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Brittle Failure of Steel-Plate Structures

By M. E. SHANK. (From *Mechanical Engineering, U.S.A.*, Vol. 76, No. 1, January 1954, pp. 23-28, 6 illustrations)

The problem of brittle failure was brought into sharp focus during World War II with the breaking up at sea and at the dockside of welded-steel merchant vessels, especially Liberty ships and T-2 tankers. Data relating to ship failures have been well correlated, and a great amount of research has been stimulated. As a result, much light has been shed on problems relating to the brittle failure of steel. No similar central repository exists in the case of non-ship structures. A survey was therefore undertaken to gather and correlate such data, in order to supplement the study of the ship-failure problem. This article is a brief summary of that survey.*

CARBON-STEEL plate, when stressed in an ordinary tension test, normally fails in ductile fashion. There is considerable energy absorption, accompanied by plastic deformation. This same material, however, under the proper conditions, can fail in a brittle manner. Three conditions can combine to bring about such failure :— (1) Low temperature, such as that existing in the ambient atmosphere. (2) The presence of a notch, introducing tri-axial stress. Any defect, such as a welding crack, or void, or a crack left by a punching or shearing operation, can serve as a notch which will initiate brittle failure. Thus, the term "notch brittleness" is often used. (3) High strain rate, or impact loading. This factor, however, is not necessary for the initiation of brittle failure. Most non-ship brittle failures occur under completely static conditions.

When brittle failure occurs, it may be recognised by several characteristics. Among these are the speed at which fracture occurs (approaching several thousand feet per second), almost complete lack of ductility, negligible energy absorption, and a brittle or faceted appearance of the fractured surface. Moreover, the fractured surface often has a characteristic "chevron" appearance, the apices of the chevrons pointing to the origin of fracture. Finally, when steel plate, taken from a structure which has failed in a completely brittle manner, is tested in an ordinary tension test, it manifests a high degree of ductility and strength. This last characteristic was extremely baffling to engineers who first encountered the phenomenon.

As early as 1879, members of the British Iron and Steel Institute complained of the mysterious cracking of steel in a brittle manner, with no ductility, usually in cold weather. In at least one case, samples from such plates subsequently met all strength and ductility requirements of Admiralty tests. The first failure of an engineering structure, however, was, apparently, at Gravesend, Long Island, in 1886, when a standpipe, 250 ft in height and 16 ft in diameter at the base, failed during a hydrostatic acceptance test, when the water reached a height of 227 ft.

Many more catastrophic failures of riveted structures, such as a gas holder, water tanks, and oil tanks, occurred in later years, including the Boston disaster of 1919, when a tank containing 2,300,000 gallons of molasses burst open. Much conflicting testimony was presented as to the cause of this disaster, but it was here that the significance of the chevron pattern, already mentioned, in a service failure was recognised.

Several bridge failures have also been reported, including three of the fifty Vierendeel truss type of bridges built across the Albert Canal in Belgium just prior to World War II, and the collapse of the Duplessis Bridge in Canada in 1951.

In the case of the Albert Canal bridges, a thorough investigation was later undertaken by two Germans. They reported that most failures had initiated in welds, and that many welds were defective. They found that on notch-impact (Charpy) tests, practically all specimens were brittle (at least in part) at the failure temperature. Their conclusions stated that the accident was caused by (a) multi-axial restraint and residual stress, (b) low ambient temperature, and (c) the low notch-impact characteristics of the steel. They seriously questioned whether non-killed bessemer steels should be used in thick plate, despite good static-tension properties, since the notch-impact properties were unsatisfactory.

Similarly, the brittle failures of many pressure vessels, oil-storage tanks, a smoke-stack, and a penstock have been reported. Three interesting failures in oil-storage tanks occurred in new structures which had never been filled, and which were standing empty at the time. The weld overfill on the seams inside the tank had been chipped flush during erection, leaving tiny notches. Following a sharp temperature drop, long cracks appeared across the welds, entering the plates on either side.

One of the most interesting situations, however, is that of brittle failures on high-pressure gas transmission lines which have occurred in the last few years. Apparently, no technical details on any specific pipe-line accident have been released. An interesting speculation may be made, however. Following a split, the gas pressure will be released by an elastic wave travelling at the speed of sound in methane, approximately 1300 fps. On the other hand, experimental values of 2750 to 6600 fps have been measured in brittle fracture of steel in the laboratory. Thus, it appears that the gas discharge-pressure wave will never catch up with the brittle crack. The crack tip is therefore always travelling in a stressed area. The gas industry is sponsoring a considerable amount of research on the brittle-failure problem.

DISCUSSION OF RESULTS

Examination of the histories of brittle failures in non-ship carbon plate steel structures demonstrates that brittle fracture is not of recent origin, and that it did not begin with the advent of welding. It also is demonstrated that brittle fracture in non-ship structures is the same phenomenon as that occurring in ships. This latter statement may seem an obvious one, but nevertheless it should be made.

Static Loading: In early research work on the subject of brittle fracture, all the testing methods used

*Based on a report to the Committee on Ship Structural Design, National Academy of Sciences—National Research Council (U.S.A.), entitled "A Critical Survey of Brittle Failure in Carbon Plate Steel Structures other than Ships."

to reveal brittleness employed impact-loading. This supported the opinion, widespread even in recent years, that brittle fracture in steels resulted from impact-loading. It was, however, known that if a specimen contained a sharp, deep notch, brittle failure could be induced by slow bending or slow tension. Mesnager, in 1906, used this fact in developing the theory of tri-axial tension in notch brittleness. In the case of non-ship failures, only 5 out of 64 definitely could be connected with the phenomenon of impact. Thus, brittle failure can occur in the presence of static loading, if the proper conditions of temperature, tri-axiality (notches), and stress are present. Indeed, about 10 per cent of all very serious ship failures occurred at the dockside or in a calm sea.

Failures in Riveted Structures: In three cases of early riveted-structure failures, it appears that the brittle cracks crossed one or more riveted joints in passage. Exact details of the crack paths are now unobtainable. However, it is well demonstrated in welded ships that on fairly rare occasions brittle cracks can propagate across special longitudinal riveted seams installed as crack arresters. These crack arresters are similar to the butt straps used in non-ship riveted constructions. All plate welds terminate at a slot behind these arresters.

Comparison of Riveted and Welded Structures: In comparing riveted and welded structures, failures in the latter seem to have occurred more frequently. This may be a totally deceptive conclusion, however, since no basis for comparison exists. Structural methods have changed in intervening years, different materials are used, and the total numbers of riveted and welded structures built are unknown. In the past, moreover, brittle failure has often gone unrecognised. For speculative comparative purposes, however, ship statistics may be examined. About 6000 ships, built between 1938 and 1948, are used as a basis. Since 1938 there have been about four times as many welded ships built as ships with riveted hulls or decks. Data presented show that for the same material, and essentially the same quality of workmanship, both the frequency and severity of fractures in ships increased as the amount of welding increased.

Thermal Stresses: In eleven non-ship welded failures, and in five riveted failures, there had been a sharp atmospheric temperature change just prior to fracture. Two of these changes were temperature rises, the remainder were temperature drops. As would be expected, no data seem to be available on thermal stresses in tanks and pressure vessels. These stresses seem to be important, however, in some degree. Thermal stresses have been responsible for initiation of several failures in ships, and studies of thermal stresses in ships are available. It is probable that thermal stresses in themselves, without additional factors (such as notches), are not too important in non-ship structures. The point warrants further investigation.

Residual Stresses: In eight cases of non-ship failure, on-the-spot investigators blamed residual stresses. Little or no information is available on the measurement of residual stress in full-size non-ship structures. The results of ship investigations, however, have indicated that the basic welding stress patterns were practically the same, regardless of the type of ship or where it was built. Thus, the results of these investigations probably can be applied directly to non-ship plate structures, at least qualitatively. It was found that, when a butt-weld bead was laid down, longitudinal tensile stress arose along the length of the centre line of the deposited metal. The value of these stresses approached the yield point. Values of transverse stress across the weld were found to be low, about 2000 to 10,000 psi in tension. Naturally, compressive stresses must exist in the parent plate.

The question of relief of residual stress in service must then be considered. Does the stressing of a pressure vessel in service, or the loading and unloading of a bridge in traffic, for instance, cause yielding and relief of residual tensile stress in a weld? For non-ship structures the problem remains largely unanswered, except for some scattered and probably unreliable measurements. In ships, however, it has been found that the magnitude of locked-in stresses is not reduced materially by the working of the ship at sea. Thus, since all welded ships contain locked-in stress, and these stresses are not reduced in service, and since only a fraction of ships suffers casualties, locked-in stresses are not, by themselves, the prime cause of ship failures. Likewise, most non-ship structures continue to stand undamaged.

In structures where defects exist, however, residual stresses must be reckoned with as being able to initiate failure, either by themselves or, as is more likely, in combination with other factors. The recent failure of three new, unfilled oil-storage tanks in Europe by large cracks running across the weld could have been initiated only by residual stress. These cracks were found to have started in marks left by chipping chisels. Undoubtedly, the full role of residual stress in helping to cause failure is not understood completely, even though there is evidence to show that stress relief will improve performance of materials in some measure.

Composition of Materials: Other factors shown to be important are the chemical composition of plate and metallurgical variables. For steels which are otherwise generally similar, a fully killed (deoxidised) steel will have a lower ductile-to-brittle transition-temperature range than a semi-killed or rimmed (non-deoxidised) steel. Decreasing the ferritic grain size, normalising, and use of a lower finishing temperature in hot rolling all serve to lower the ductile-to-brittle transition-temperature range. Increasing the carbon and phosphorus contents markedly raises the transition temperature, thus promoting susceptibility to brittle failure. Increasing the manganese content has the opposite effect. Other chemical elements play less marked, but fairly well-defined, roles.

In view of the foregoing, it would seem that the practice of using rimming steels in the past may have contributed to brittle failure in some cases. It also is indicated that the practice of using higher carbon steels, either inadvertently or deliberately to obtain high strength, may have been contributory. In general, there seems to have been a lack of attention in the past as to steel compositions, at least insofar as the effect of composition on possible brittle failure is concerned.

Cold Forming: Cold forming sometimes may play an important role in brittle failure. Cold forming of steel plate is a necessary part of the fabrication of almost all engineering structures. Several interesting pieces of research have been done on this problem with ASTM steels in common structural use. It was found that with a killed steel a small amount of permanent deformation raised the ductile-to-brittle transition-temperature range only a relatively small amount. In a rimmed steel, however, the same amount of plastic deformation raised the transition temperature by three times as much. The large difference is probably due to the great susceptibility to strain-ageing (precipitation following cold work) in rimmed steels. Normalising at 1600° F consistently restored ductility and lowered the transition temperature, while heating to 1150° F was not consistently equally effective. For both the rimmed and killed steel, large amounts of plastic strain raised the transition-temperature range by about the same amount. Thus, the initial cold working is most damaging in the rimming steel here tested, and more cold work has only a little additional effect. Data do not seem to be available on the effect of cold forming on the transition temperature for steel taken from failed non-ship structures. Nevertheless, it is clearly implied that extensive cold work will tend to increase susceptibility to brittle failure.

Welding Processes: The process of welding is of importance in the study of brittle failure. As shown by several laboratory investigations, welding in itself contributes many metallurgical variables to the state of the metal in the weld and in the heat-affected zone. Moreover, behaviour of the as-rolled plate gives no evidence of characteristics in the welded material. Unfortunately, practically no data are available from failed non-ship structures concerning the details of welding procedures. Consequently, it is impossible to assess, in general, the role of metallurgical variables, resulting from welding, in the initiation of brittle failure.

Structural Defects: Structural defects, such as cracks and stress concentrations, are most important in the phenomenon of brittle failure. In non-ship structures for which data are available, the preponderance of failures has been initiated in both riveted and non-riveted cases at cracks left by punching or shearing, at plate offsets, weld voids, poor weld-probe replacements, poorly repaired welds, and other defects resulting from improper fabrication procedures. Of those studied, only two failures were initiated solely by the effect of stress concentrations designed into the structure. Modification of the design of these latter structures seems to have been initiated by a combination of design and fabrication defects.

In the case of welded ships built during World War II, however, fractures often originated at points where poor welded-design practice had been utilised (i.e., sharp hatch corners in the Liberty ships). Following design modifications, on the other hand, the origins of most recent failures in these ships have been traced to defective workmanship. It also was concluded for

(*Concluded on page* 162)

FRANCE

The "Vibrotor" Vibration Exciter

By G. HENTSCHEL and S. SCHWEIZERHOF. (From *La Recherche Aéronautique*, No. 37, January-February, 1954, pp. 51-55, 10 illustrations.)

MANY types of exciter equipment have been built for generating mechanical vibrations. They are employed in laboratories for vibration tests, fatigue tests, etc. and in industry for vibratory conveyors, stirrers, etc. These exciters may be mechanical (e.g., of the balance-weight type), hydraulic, pneumatic, electromagnetic, electrodynamic, etc. The practical value of each type depends on the working conditions considered and it is not easy to generalise as regards the requirements to be fulfilled.

However, there are certain features which are desirable in a large number of cases, i.e., small mass of the moving parts producing the excitation, small value of the reaction due to vibration amplitude on the exciting force, small variation of the force as a function of the driving frequency, good efficiency (i.e., low-cost source of vibratory power), and robust construction.

As a further development in this field, a new, patented torsional exciter, known as the "Vibrotor," has been produced in France, and embodies most of the desirable features mentioned above.

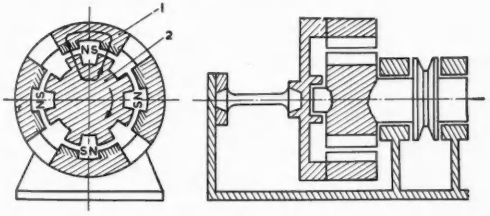

Fig. 1. **Basic principle of the "Vibrotor."**

The main features of the "Vibrotor" are indicated in Fig. 1. The stator (1) is provided with a number of permanent magnets, and the soft-iron rotor (2), with a corresponding number of teeth, is driven by any type of motor. There are no electrical windings. When the rotor is free, its teeth locate themselves under the poles of the permanent magnets. In this position of equilibrium, the potential energy of the magnetic circuits has its maximum value. This energy is concentrated mainly in the flux-gaps between the rotor teeth and the poles of the stator. When the rotor is rotated, the magnetic forces produce a restraining torque acting on the teeth until these pass through the middle position between the poles of the magnets. At this point, the magnetic forces change in direction and an accelerating torque is produced as the teeth come nearer to the following poles, and again increase the magnetic energy. Thus, a complete cycle of vibration is obtained each time the teeth pass from one pole to the next. The uniform rotation of the rotor produces a vibratory reaction torque on the stator and hence on the object to be vibrated, which is connected to the stator.

The vibration frequency is proportional to the rotor speed and the number of poles. The vibratory torque is also proportional to the number of poles, but is independent of frequency, since the energy of the magnetic circuits is not a function of the running speed.

If permanent magnets are used, the "Vibrotor" requires no windings, and this clearly distinguishes it from the usual electromagnetic and electrodynamic exciters. However, even if the magnetic fields are excited by d.c. windings (to make possible a continuous adjustment of the vibratory torque), the unit still retains its basic feature, i.e., the direct conversion of rotating into vibratory torque, without intermediate use of electric energy. It thus develops a very favourable efficiency.

The "Vibrotor" is generally driven by a variable-speed electric motor connected to the mains. The arrangement provides, therefore, a source of vibratory power at low cost. This is particularly advantageous for high power outputs. In comparison, the usual electrical exciter systems require a variable-frequency generator and a broad-band power amplifier, which add to the cost of the equipment.

Comparing this apparatus with electromagnetic systems, it should be recalled that the force generated by the latter systems, for a given voltage at the winding terminals, is inversely proportional to the square of the frequency. To maintain constant the force in such systems, it is necessary to vary considerably the output voltage of the amplifier as a function of frequency, and corresponding adjustments apply to the output transformer. This condition is difficult to fulfil with a single winding for a large range of frequencies. As regards electrodynamic devices, their vibratory force is independent of vibration amplitude and frequency, if the excitation current is kept constant. However, apart from the high cost of the power unit, these systems have a very poor electro-mechanical efficiency and are not generally very sturdy mechanically.

Certain difficulties arise in developing a "Vibrotor" for considerable power at high frequencies, e.g., for a peak-value torque of 600 kg-cm at 5,000 cps :—The excitation of the vibratory mechanical torque gives rise

to an alternating voltage at the exciter-coil terminals. For large forces at high frequencies, although this voltage is only a secondary factor (in contrast to the case with electromagnetic systems), it may reach considerable values, which necessitate precautions against breakdown. Furthermore, it is necessary to avoid, by means of an inductance inserted in the excitation circuit, the production by this alternating voltage of a reaction current which would reduce the vibratory torque appreciably. These problems, however, need to be considered only when dealing with vibrators of exceptionally high power. Vibrotors constructed with permanent magnets avoid these more complicated features.

The vibrating mass of the apparatus should be small with respect to the value of the alternating torque, to avoid appreciable effects on the frequencies and natural vibration forms of the objects to be vibrated. The arrangement in Fig. 1 is not very favourable in this respect. However, as will be shown later, it is possible to reduce the vibrating mass considerably. In the basic arrangement, the reaction torque is obtained as a result of the relative displacement of the poles of the rotor and the stator. Actually, a similar result can be obtained by inserting magnetic discs between the poles. These discs receive the vibratory torque and transmit it to the object to be vibrated. In this way, the mass transmitting the vibration can be made fairly small.

FEATURES OF VARIOUS " VIBROTOR " DESIGNS

Vibrotor No. I: This exciter (see Fig. 2) has a two-pole stator (1), a rotor (2) with 20 teeth, and a cylindrical cage or grid of magnetic elements (3), which can rotate freely between the stator and the rotor. The grid is rigidly coupled to the object to be vibrated.

Vibratory torque is produced only between the rotor and the grid, both of which vibrate with amplitudes inversely proportional to their moments of inertia. The magnetic grid is designed so as to have a minimum moment of inertia, whereas that of the motor-driven rotor is increased by a flywheel, so as to avoid a loss of energy in the direction of the drive. The advantages are the possibility of exciting rotating, as well as stationary specimens (e.g., clamped specimens, or the blades of a turbine rotor under rotating conditions), and the use of a rotating bearing as a guide for the vibrating grid, thus avoiding the disadvantages of an oscillating bearing surface, i.e., seizure and wear.

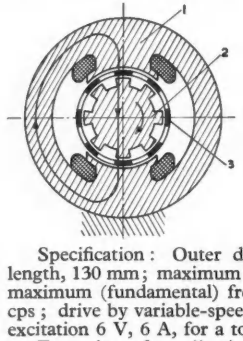

Fig. 2. **Schematic arrangement of " Vibrotor " No. I.**

Specification: Outer diameter, 150 mm; overall length, 130 mm; maximum vibratory torque, 80 kg-cm; maximum (fundamental) frequency of excitation, 1500 cps; drive by variable-speed motor of 300 W; magnet excitation 6 V, 6 A, for a torque of 60 kg-cm.

Examples of applications: A rectangular-section steel rod of 3 × 20 × 100 mm, clamped at the centre, was vibrated at its 9-node frequency (354 cps) with amplitudes of ±1·5 mm at the ends of the rod. With an unfavourable clamping arrangement (sudden change in cross-section), rupture occurred near the clamped position after a few minutes. Compressor blades of duralumin were excited in bending, while mounted as under service conditions. One-, two- and three-node vibrations were obtained (the latter at 2690 cps was excited by a harmonic of the vibratory torque). Under one-node conditions, fracture occurred near the blade root, with a blade-tip amplitude of ±6 mm, after a maximum of about 4 hours testing. In other tests, the blades of a compressor rotor completely assembled were excited in bending at their fundamental frequency, with blade-tip amplitudes of ±1 mm.

Vibrotor No. IIa: This machine was specially designed for tests of turbine or compressor blades, with excitation at the blade tips. The grid is replaced by individual magnetic elements, fixed to the ends of the blades. The advantages in this case are that the blades are excited at points of maximum deflection, thus allowing maximum energy input to be obtained for a given force; that no special clamping arrangements are required; and that, with rigidly-mounted blades, there is no energy loss at the blade roots.

The small laminated pole-pieces fitted on the blade tips slightly alter the form of the vibration. Turbine blades of magnetic material can be excited to some extent without pole-pieces.

Specification: Maximum excitation force at each blade tip ±0·2 kg; maximum excitation frequency, 5,000 cps, obtained by means of a rotor with 60 teeth driven at 5000 rpm. The dimensions are the same as those of the Vibrotor No. I.

Vibrotor No. IIb: In this machine, which is now under construction (Fig. 3), the entire excitation circuit is designed to rotate. This eliminates air-gap losses and appreciably increases the vibratory torque. The exciter coil also rotates and is supplied by means of slip-rings.

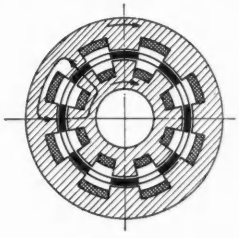

Fig. 3. **Schematic arrangement of " Vibrotor " No. IIb.**

Specification (design stage): Outer diameter, 350 mm; length, 400 mm; maximum vibratory torque, ± 600 kg-cm; maximum excitation frequency, 5,000 cps; maximum angular vibration amplitude, approximately ±1·5 deg (corresponding to a deflection of ±4 mm at the outer periphery of the vibrating drum).

ADDITIONAL TESTS AND APPLICATIONS

Vibrotor No. I has been operated for many hours at high frequencies for the fatigue rupture of testpieces. Deliberately rough handling has proved it to be a sturdy and reliable exciter. It is now being used for methodical vibration investigations of turbine and compressor blades. The blades are explored by means of a small electrodynamic pick-up. The voltage induced in the pick-up exciter coil and the voltage induced in the corresponding exciter coil of the Vibrotor are used to obtain Lissajous figures on an oscilloscope screen. These give the amplitude and phase of the vibration at each test point. It is worth noting that the vibratory energy supplied by Vibrotor No. I is sufficient to produce appreciable heating at the nodes of the higher modes of vibration.

The Vibrotor opens up new possibilities in the field of excitation at high frequencies with high power outputs. The frequency range is from 10 to 10,000 cps, the upper limit being determined by the rigidity of the mechanical connection between the magnetic grid and the object to be vibrated. Apparatus of this kind can be used for fatigue tests at the higher modes, dynamic balancing of rotors, etc. The first series of tests carried out with the small-size machine have justified the study and development of larger units, which should have interesting engineering applications.

Determination of Temperature Distribution in Gas-Turbine Rotor Bodies and Cylinders by the Electrolytic Tank Method

By H. BAUMANN. (From *The Brown Boveri Review*, Vol. 40, No. 5/6, 1953, pp. 189-196, 12 illustrations.)

This article shows how, by means of the analogy between the flow of heat and electric current, the electrolytic tank can be used for temperature determinations. The model rules stated permit the conversion of thermal quantities into their electrical equivalents. The practical application of the method is described and the temperature distributions obtained in the electrolytic tank are illustrated for a gas-turbine rotor body and the inside of a gas-turbine cylinder.

THE gas turbine has proved its worth in many different designs and in the most widely varying fields of application. Its use as a prime mover now depends largely on its economical advantages. These are considerably enhanced by the cooling of parts which are highly stressed thermally and mechanically. Cooling permits a high temperature at the turbine inlet and the use of low-alloy steels. High temperature ensures low fuel consumption and a high specific useful output ; low-alloy steels reduce material prices and machining costs.

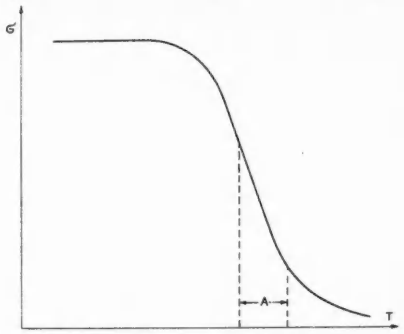

Fig. 1. **Strength of a type of steel used in gas-turbine construction at high temperatures, as a function of working temperature.**

σ = Creep-rupture strength for 10^5 hr.
T = Temperature.
A = Main temperature range of steel used in gas-turbine construction.

The importance of knowing the exact temperature distribution in the cooled components is illustrated by Fig. 1, which shows the relation between the creep-rupture strength σ and the working temperature T, on the basis of 10^5 hours, of a steel used in gas-turbine construction. From this it can be seen that in the mainly used range of temperatures A, rupture strength varies considerably with temperature. As a result, an accurate knowledge of the temperature distribution arising from cooling is of very great importance for assessing safety factors and for utilising materials to the best advantage.

SOLUTION OF THE HEAT CONDUCTIVITY PROBLEM

Steady heat flow is described by the differential equation

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = 0$$

An analytical solution is not usually possible for the geometrical shapes encountered in practice. The flux-plotting method is laborious on account of the kind of boundary conditions peculiar to heat-transfer problems. Owing to the frequent occurrence of such problems, an analogy method has been developed. Two phenomena which are described by the same differential equation can be considered, i.e., a stretched membrane and an electric current, respectively. Although the membrane analogy is very simple and illustrates the problem clearly, the boundary conditions usually occurring in heat-transfer problems can be imitated only with difficulty. The electric current analogy alone also permits three-dimensional problems to be solved. With this analogy, the heat flow in a solid body is represented by the flow of electricity in an electrolyte. The equation of boundary conditions is solved with the electrical resistances adjusted to correspond to the heat-transfer resistance.

MODEL RULES

To ensure similarity between the temperature distribution of the original and the electrical potential distribution in the model, the following conditions of similarity must be fulfilled :—

Geometrical Similarity : The need for geometrical similarity between the original and the model is obvious. For all lengths the following relations must hold :

$$L_{A1} : L_{A2} \ldots : L_{An} = L_{M1} : L_{M2} \ldots : L_{Mn}$$

where L_A and L_M are the respective lengths of the original and the model.

Similarity of Potentials : The electrical potential in the model corresponds to the temperature in the original. At every corresponding point in the original and model the temperature T and electrical potential φ must remain in a certain relationship :

$$T_1 : T_2 : \ldots : T_n = \varphi_1 : \varphi_2 : \ldots : \varphi_n$$

Similarity of Boundary Conditions : The thermal boundary condition for heat transfer by convection is

$$\frac{\partial T}{\partial s_\mu} = \alpha \left(\frac{1}{\lambda} \right) (T_G - T_W)$$

where s_μ is the gap width perpendicular to the surface, α is the heat-transfer coefficient, λ the thermal conductivity, and T_G and T_W are the gas and wall temperatures respectively.

Similarly, for the electrode immersed in an electrolyte of conductance $1/\rho$, ρ being the specific electric resistance, the electrical boundary condition is :—

$$\frac{\partial \varphi}{\partial s_\mu} = \left(\frac{1}{R_E F_E} \right) \rho \, (\varphi_P - \varphi_E),$$

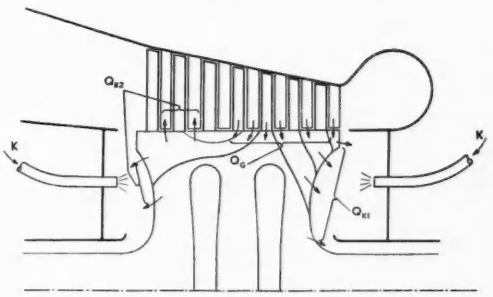

Fig. 2. **Heat flow in a gas-turbine rotor.**

Q_G = Quantity of heat transferred from motive fluid to rotor body.
Q_{K1}, Q_{K2} = Heat carried away by cooling air (K) or by cold motive fluid.

where R_E and F_E are the electrode resistance and electrode area, and φ_P and φ_E the potential at the potentiometer and electrode, respectively.

This shows the relation between the thermal and the electrical boundary conditions which apply. With this, the Biot number B is obtained as a dimensionless quantity[1] :—

$$\text{thermal } B_A = \frac{\alpha L_A}{\lambda}\ ;\ \text{electrical } B_M = \frac{\rho L_M}{R_E F_E}.$$

where the factor L is any length which is common to both the original and the model. In order to achieve similarity of the boundary conditions at every point on the surface, the Biot numbers of the original and the model must be equal, so that $B_A = B_M$.

With these conditions it is possible, knowing the thermal values, to determine the electrical equivalents. In particular, the resistance R_E can be established after choosing the size of the electrode F_E.

Practical Application of the Electrical Analogy Method

The following example of a cooled gas-turbine rotor body demonstrates the practical application of the analogy method (Fig. 2). The rotor body receives a quantity of heat Q_G from the motive fluid, partly by direct contact and partly indirectly through the blades. At the inlet end the cooling air K removes a quantity of heat Q_{K1} from the body. The exhaust gases, which are at a low temperature owing to the work done in the blading, also have a cooling effect at the outlet end, and this can be increased by additional cooling air. The quantity of heat carried away is Q_{K2}.

Effective Gas Temperature :—The effective gas temperature T_{eff} is determined by calculating the temperature drop during expansion. It must be remembered that, with the large relative velocities occurring in the blading of turbo-machines, the effective temperature for heat transfer is made up of the static gas temperature T_{Gst} and the temperature quantity $rw^2/2c_p$ recovered from the kinetic energy of the relative flow, where r is the recovery factor, w is the relative velocity, and c_p is the specific heat :

$$T_{eff} = T_{Gst} + rw^2/2\,c_p$$

For laminar flow, the recovery factor r can be expressed[2] in terms of the Prandtl number Pr as

$$r = \sqrt{Pr}$$

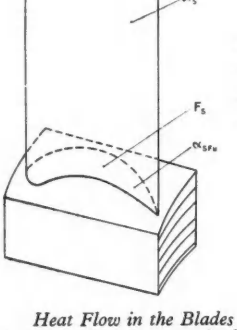

Fig. 3. **Heat flow in a blade.**

α_S = Heat-transfer coefficient between gas and blade.
F_S = Blade-root cross-section.
α_{SFu} = Heat-transfer coefficient between gas and blade root.

Heat Flow in the Blades : A large proportion of the heat entering the rotor body flows through the blades. Heat transfer values a_S for different blade profiles have been known for some time[3] and have been supplemented

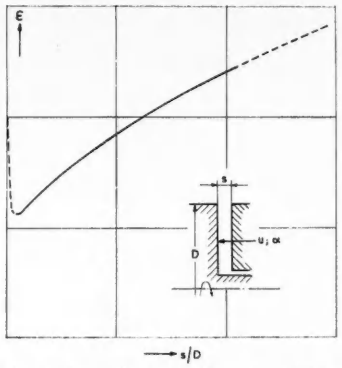

Fig. 4. **Heat transfer at the face of a rotating disc.**

D = Disc diameter.
s = Gap.
ϵ = Dimensionless quantity for determining heat-transfer coefficient.
u = Local peripheral velocity.
α = Local heat-transfer coefficient.

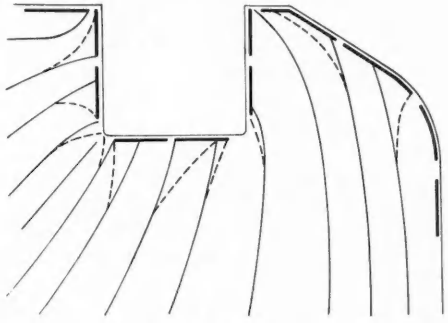

Fig. 5. **Effect of electrode width on potential distribution.**

——— = Electrode.
——— = Equipotential lines with electrodes of the width shown.
- - - - - Equipotential lines with electrodes of twice the width.

by recent publications[4]. Assuming uni-dimensional heat flow the heat-transfer coefficient α_{SFu} is derived, referred to the temperature difference between the gas and the blade root, as well as to the root cross-section (Fig. 3) :

$$\alpha_{SFu} = \lambda_S\, m \tanh (m\, L_S)$$

where L_S and λ_S are respectively the length and thermal conductivity of the blade, and

$$m = \sqrt{\frac{\alpha_S\, U_S}{\lambda_S\, F_S}},$$

U_S being the periphery of the blade.

Normally, the values for $(m\, L_S)$ are so large that $\tanh (m\, L_S)$ is practically equal to unity. The heat-transfer coefficient can therefore be written as

$$\alpha_{SFu} \approx \sqrt{\alpha_S}$$

As a result, it follows that any inaccuracy in the determination of the heat transfer at the blade surface has only about half the effect on the resulting heat transfer to the rotor body surface.

Heat Transfer at the Rotor Body Face : The cooling effect of the cooling air K (Fig. 2) depends largely on the heat transfer at the body face. As no actual heat-transfer figures for a disc rotating in a housing are known, use was made of Reynolds analogy between momentum and heat transfer. Recent figures have been

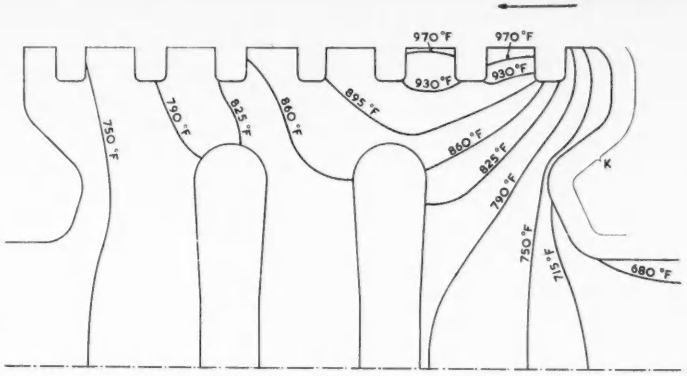

Fig. 6. **Temperature distribution in a gas-turbine rotor body.**

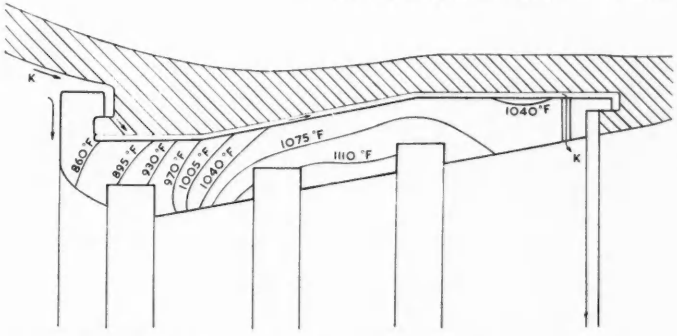

Fig. 7. **Temperature distribution inside a cooled cylinder.**

published on the effect of housing size on disc friction[5]. In this way it was possible to use a theoretical method for reaching quantitative results for the heat transfer of a rotating disc. The result can be summarised in terms of the Nusselt number *Nu*, the Reynolds number *Re*, and the Prandtl number *Pr*, as follows :—

$$Nu = \epsilon \, Pr \, Re^{0.818}$$

Re and *Nu* are formed by the gap width s and the local velocity and heat transfer values. The variation of ϵ can be seen from Fig. 4. Owing to the centrifugal motion of the boundary layer, quite considerable values for the heat transfer are reached, as can be proved by substituting actual figures.

Arrangement of the Electrical Circuit : The current in the electrical model must correspond to the heat flow in the original. At every point in the original at which there is an exchange of heat, an electrode must be fitted in the model, the number and size depending on the accuracy with which the temperature distribution is to be determined. Fig. 5 shows the effect of electrode size on potential distribution. A small number of large electrodes distorts the field towards the surface, while in the centre the potential field is reproduced accurately. If accurate results are also required at the surface, electrodes must not be used sparingly.

Generally, the coefficient of heat conduction λ of the rotor body material is assumed to be constant; in fact, however, it varies considerably with temperature. This variation can be simulated in the experiment by varying the electrolyte depth H in the relation $H = H'\lambda/\lambda'$, and this can easily be effected if the model base is made of a plastic material.

Description of Apparatus : In order to avoid disturbances due to polarisation and electrolysis, a 50-cps alternating current at 20 V is used, with distilled water as electrolyte. A probe follows the required equipotential line and, to obtain the maximum sensitivity of the bridge, phase differences caused by the probe and lead capacitances are compensated for by a variable capacitor. A cathode-ray oscillograph is used as a zero-indicating instrument. This method has proved to be extremely sensitive and makes possible very exact plotting of the equipotential lines, even when the gradients are very steep. The probe is mounted on an easily adjustable cross-frame and is provided on its upper part with a bulb and a lens with cross-wires directed upwards. With this device it is a simple matter to project the position of the probe on to a drawing mounted on a glass plate.

Experimental Results

In Fig. 6 the measured temperature distribution in a gas-turbine rotor body, obtained on the basis of the following data, is shown :—

Temperature at turbine inlet	1110° F
Temperature of cooling air	610° F
Pressure at turbine inlet	64 psi abs
Pressure at turbine outlet	14·2 psi abs

The measurements give a maximum rotor temperature of 985° F, which occurs at the surface. Fig. 7 shows the temperature distribution inside a cooled cylinder for an inlet temperature of 1380° F.

The results show clearly that by cooling (K), it is possible to limit to permissible values the temperature of parts in contact with the hot gases.

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Solar Heat Absorbers and Accumulators

By G. VINACCIA. (From *Rivista di Ingegneria*, Vol. 3, Nos. 11 and 12, November and December, 1953, pp. 1242-1246, 1365-1368, 12 illustrations.)

The use of solar energy for domestic heating and industrial purposes has several possibilities, which have been the subject of various recent reports. On the basis of the information available on the subject, this article sets out the requirements to be fulfilled by solar heat absorbers developed by the author.

THE thermal energy of the sun at the outer limits of the earth's atmosphere is fairly constant, with a mean value of about 7·1 B.T.U./sq ft per minute, or about 4300 B.T.U./sq ft per day, assuming a daily average of 10 hours of sunshine. However, only a fraction of this radiation reaches the earth's surface, owing to atmospheric absorption, depending on the " transmittance " of the atmosphere, which is a function of the moisture and dust content, the radiation path (relative to a path vertical to the earth's surface), the hour angle from solar noon, and latitude. In addition, the effective number of hours of insolation and their distribution throughout the year are of importance.

The mean amount of solar energy received on a flat surface constantly normal to the direction of radiation, on the basis of calculations made by Angot and Dorning, and reported by Amerio[1], for average atmospheric transmittance, varies with the period of the year, as follows :—Winter solstice, 2325 B.T.U./sq ft per day at the equator (1400 at 30 deg and 600 at 45 deg latitude) ; equinoxes, 2550 B.T.U./sq ft (2400 and 1600) ; summer solstice, 1850 B.T.U./sq ft (2750 and 2900). Average values are 2400 B.T.U./sq ft per day at the equator, 2450 at 30 deg latitude, and 1650 at 45 deg latitude.

The total average insolation is approximately 4400 hours per annum and is theoretically constant for the entire earth. In fact, however, it varies from place to place, according to the number of clear days and hours of unobscured solar radiation. Thus, for instance, California has, on the average, 3160 hours of clear sunshine (72% of the theoretical value) and 200-300 clear days per annum, while in Rome the total number of clear days per annum averages 112, with 1800 hours of sunshine (41% of the theoretical value).

DESIGN OF SOLAR HEAT ABSORBERS

In order to absorb a maximum amount of direct radiation, solar heat absorbers are generally provided with a blackened surface and, to increase the amount of reflected radiation, all surrounding surfaces are painted white. Glass-covered absorbers receive less heat than uninsulated absorbers, owing to the reflecting properties of glass, but they also cool less rapidly when insolation ceases. The inclination or tilt of the absorber from the horizontal is also an important factor, as the percentage radiation received varies according to a cosine law, decreasing from 100% at an angle of incidence of 90 deg to zero at 0 deg.

Owing to variations in the amount of heat received, it is necessary to add to the radiation absorber an accumulator arrangement with a circulating liquid in which the heat is stored. Alternatively, the absorber can be operated with auxiliary gas or electric heating systems, for use when the supply of heat is insufficient. With regard to the application of a solar heat absorber to the distillation of water, Bullard[2] indicated in this respect a very conservative figure of 0·014 kW per square foot of absorber surface. With the equipment described below, it is considered that a yield of 0·042 kW/sq ft could be obtained. In tropical and semi-tropical regions, this application would be a great advantage. With a heat-receiving surface of 1000 sq ft, it would be possible, for instance, to distil 300 Imp. gal of water per day.

On a more modest scale, but of great importance for its wide possibilities of application, is the use of solar energy for the domestic cooking of food. In India, solar-heat cooking equipment is already in practical use, and in England a solar cooker of 100 W output, using a mirror of about 3·2 sq ft, is being developed for tropical and semi-tropical countries.

In California, a centre of experimental studies on solar energy utilisation has been operating for some time at the University of California. A review of American solar-heating systems has been published by Brooks[3]. These absorb from 50 to 60% of the incident radiation and raise the temperature of the heat-receiving liquid by up to 86° F, reaching a maximum temperature of 140° F. Bullard[2] mentions that their use is declining in America ; this may be due to the excessive addition of auxiliary appliances. Brooks pointed out that glass-covered absorbers, constantly normal to solar radiation, absorb 85% of the incident radiation, whereas bare absorbers receive 96%. At an angle of incidence of 45 deg, glass-covered absorbers receive only 56% of the radiation. Furthermore, dust and dirt accumulating on the glass surface reduce performance considerably, while additional heat losses occur in the pipe conduits and the storage system.

From this brief survey it follows that an ideal solar heat absorber should incorporate the following features : (1) Bare radiation-receiving surface ; (2) simple, automatic accumulator arrangement ; (3) universal design,

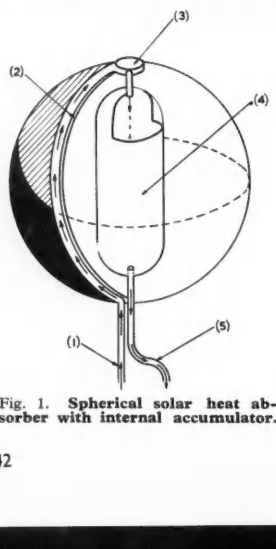

Fig. 1. **Spherical solar heat absorber with internal accumulator.**

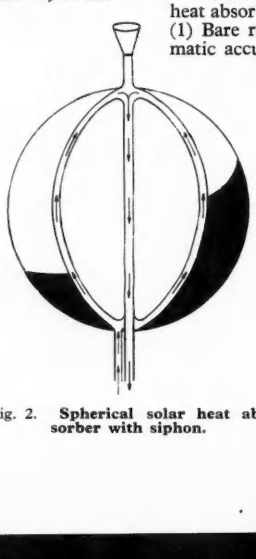

Fig. 2. **Spherical solar heat absorber with siphon.**

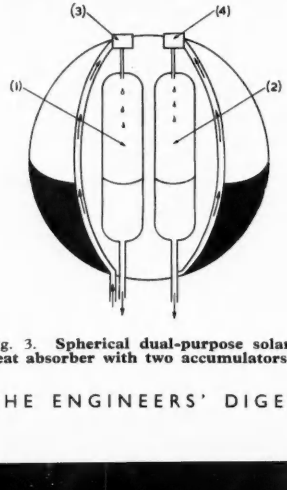

Fig. 3. **Spherical dual-purpose solar heat absorber with two accumulators.**

suitable for all latitudes and seasons, presenting a constant effective surface area to radiation; and (4) independent operation, without the need for auxiliaries or mechanical devices.

The Vinaccia Spherical Absorber

The Vinaccia V 947-48 solar-heat absorber and accumulator is illustrated in Fig. 1. The absorber consists of two concentric spheres of sheet metal, separated by an interspace of about 0·8 in. for the circulation of the liquid used as the working medium. The outer surface is blackened and the inner surface is provided with a layer of insulating material (2). The apparatus is mounted on any suitable arrangement to raise it above the level of the surrounding surface. Owing to its spherical shape, the absorber always presents the same amount of surface area to solar radiation, at any latitude or time of day, without the need for any mechanical drive.

When water taken from the mains is used to fill the interspace, the absorber can be set up above the ground at any convenient height permitted by the supply pressure, which may, if desired, be increased by means of a pump. However, the apparatus can be made to operate at a level above that of the distribution pressure, by using a siphon arrangement, as shown in Fig. 2.

Insofar as the heat accumulator is concerned, this should have minimum heat losses due to radiation, convection and conduction. Consequently, the accumulator is located inside the central cavity of the absorber, as shown in Fig. 1. When the water, introduced into the absorber *via* pipe (1), reaches a certain temperature, e.g., 115° F, a thermostat (3) opens an orifice at the top of the absorber, allowing the heated water to pass into the accumulator (4), whence it can be drawn off *via* pipe (5). The valve is closed by the thermostat when the water temperature drops below the required value.

As the surface area of a sphere is four times that of its meridian cross-section, the apparatus receives direct solar radiation plus the diffuse and reflected radiation from surrounding surfaces. The sheet-metal surface cools down considerably during the night, and use can be made of this property in arid regions where day and night temperatures are widely different. For these regions, the absorber can be designed, as shown in Fig. 3, to serve a dual purpose by providing two thermally insulated reservoirs (1) and (2) as accumulators inside the central cavity, the admission of water being regulated by two thermostats (3) and (4), for maximum and minimum temperatures, respectively.

Experimental Absorber Tests

In the first spherical absorber of this type, the two spheres were made of black iron sheet, of about 0·04 in. in thickness. The inside cavity was lined with glass wool. No accumulator was used. The approximate dimensions of the apparatus were as follows:—Outer diameter, 5 ft 3 in.; inside diameter, 5 ft 1 in.; interspace, approximately 0·8 in.; capacity of interspace, 38 Imp. gal.; outer surface area of sphere, 87 sq ft; effective (meridian) cross-sectional area, 21·7 sq ft; total weight, 155 lb. For constructional reasons, the sphere was subdivided into two halves, with the water chambers in the interspaces communicating only at the top and bottom of the apparatus. The cold water inlet was located at the top, and the hot water outlet at the bottom of the absorber.

The first tests were made with an unblackened and a blackened surface. The hemispheres were set up so as to face north and south, respectively. Temperature readings were taken from six thermometers inserted at various positions in the absorber interspaces. Additional temperature readings were subsequently taken from a cylindrical hot-water accumulator of 6·6 Imp. gal capacity, situated externally to the absorber.

During the summer, with the sun at the meridian and a radiation intensity of 4·24 B.T.U./sq ft per minute, it was found that the absorber had a maximum heat output of 4850 B.T.U./hr, or 1·07 kW, corresponding to nearly 0·05 kW per square foot of effective (cross-sectional) area. Subsequent tests, based on the temperature of 44 Imp. gal of water, showed that, with an inlet temperature of 59° F, the water reached a maximum outlet temperature of 138° F, the mean value obtained being 122° F. In these tests, the maximum output was 28,600 B.T.U. in five hours (from 7 to 12 a.m.), equivalent to 1·23 kW output or nearly 0·06 kW/sq ft of effective surface area.

It was considered that an internally-built accumulator system of the type shown in Fig. 3 would greatly increase the overall efficiency of the system, and it is planned to incorporate this in subsequent designs. Comparative costs of heating one quart of water by various methods have been assessed by Granella, taking into account the depreciation of the corresponding equipment, and it was found that, if the cost with the solar heat absorber were taken as *C*, the cost would be 2*C* with a wood fire, 6*C* with paraffin, 7*C* with gas, and 13*C* with electricity.

Vinaccia Plate Absorbers

These plate absorbers, type V 948, illustrated in Fig. 4, can be used on the roofs of factories, etc. for thermal insulation and serve at the same time as solar heat absorbers yielding an appreciable amount of useful heat. Each plate consists of a flat outer layer (1) of thin sheet metal, with a blackened surface; an intermediate plate (2) with channels (3) for circulating water over part of its length, this plate being provided with a heat-reflecting surface and located under the outer plate (1); and a layer of insulating material (cork) of suitable thickness (4), located under plate (2) and serving as a support for the entire system.

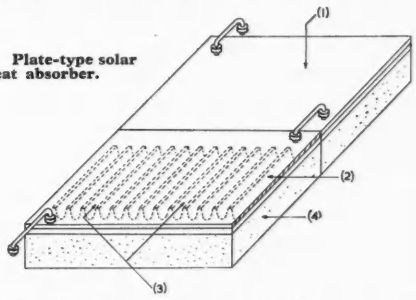

Fig. 4. **Plate-type solar heat absorber.**

The liquid circulates in the channels (3) between the two outer plates. The channels of the individual plates are joined together by specially designed tubular connections, and the entire plate assembly has one inlet and one outlet tube. Movement of the liquid can be effected by a thermo-siphon system operating on temperature differentials, a siphon, or a pump. The thermal resistance of the assembly is the sum of the resistances of the individual plates. Each plate should have a surface area of about 10 sq ft. The dry weight of a plate is then approximately 8 lb/sq ft, or about the same as that of an ordinary covering of tiles. At the equator, a 10-sq ft plate will receive approximately 18,500 B.T.U. per day, and the circulating liquid can attain a temperature of the order of 195° F. A plate-covered area of 3000 sq ft can therefore absorb 5,550,000 B.T.U. per day; assuming 50% efficiency and 10 hours of sunshine per day, this gives an output of approximately 278,000 B.T.U./hr, or about 60 kW.

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U. S. A.

Influence of Heat Treatment and Cold Working on Tensile Strength Ranges

By R. L. STEDFELD. (From *Machine Design*, Vol. 26, No. 2, February 1954, pp. 163-173, 11 illustrations.)

Conventional methods of raising strength levels by heat treating and cold working have large effects on widening the range of tensile strength of metals. This article summarises the methods for raising the strength levels for a number of these materials and points out the practical significance of these methods.

IN appraising eligible materials for a machine part, strength in tension is one of the primary factors, since this property is usually used as an index of strength of the material. However, careful consideration must be given to the variations possible in tensile strength, not only in considering tensile strength figures for evaluation, but also to permit effective appraisal of the strength potentials of any material.

Almost all metallic materials can be worked to increase strength level; many can be heat-treated. Non-metallic materials usually cannot be heat-treated or worked in the conventional sense of the terms, but other factors greatly influence tensile strength.

The effects of annealing, normalising, or stress relieving are not discussed in this article. Although these are major heat-treatment techniques, their primary purposes are either softening and increasing ductility (annealing), or producing a stabilised metallurgical structure. None of the three is carried out primarily for increasing strength level, although normalising or stress relieving may have a beneficial effect on strength by relieving internal strains.

WROUGHT CARBON AND ALLOY STEELS.

In general, steels are not used much above the 200,000-psi tensile strength range, although recently some work has been done in utilising 4340 steel at a 260,000 to 280,000-psi level—a very high value for this steel. At these high strength levels, strength-to-weight ratio is equal or superior to that of the strongest aluminium or titanium alloys.

Very careful design, however, and close control of heat-treating and manufacturing processes are necessary. Many deep-hardening steels can be heat-treated to strength levels well above this range, but the chief problems are notch sensitivity, embrittlement and quench cracking during heat treatment, and hydrogen embrittlement from pickling and plating operations. By careful control of design and processing, these hazards can be minimised, although they must be recognised and allowances made. Impact loading, for instance, which may be resisted successfully by aluminium, because of its low modulus of elasticity, may be quite a problem with a steel at these high strength levels, since the steel has tendencies to fail in a brittle manner. Actual or simulated service tests must be conducted where impact or stress concentration may be present.

Several basic facts about steels, which have often been mentioned before, deserve re-emphasising :—

(1) Steels of the same hardness produced by tempering after hardening will have about the same tensile yield strength (Figs. 1 and 2).
(2) Maximum hardness is determined by the carbon content (Fig. 3).

Thus, in thin sections, steels of equivalent carbon content produce about the same tensile and yield strength after quenching and tempering.

Section size is the controlling factor in determining whether a particular steel can be hardened to the proper tensile strength. Rate of cooling upon quenching and resulting " hardenability " are determined by the alloy content. Some steels are sluggish in response to heat treatment; the hardened structure can be obtained only for a short distance below the surface. Other steels are very sensitive; the same quenching procedure would result in much higher hardness and strength in equivalent size specimens. Consequently, these " deep-hardening " steels are usually reserved for larger pieces where strong, through-hardened structure is needed.

STAINLESS STEELS

Stainless steels fall naturally into three groups, i.e.,

Fig. 1. **Relationship between tensile strength and hardness for quenched and tempered alloy steels.**

Fig. 2. **Normal expectancy for yield-point percentage of tensile strength for quenched and tempered alloy steels.** Values in the area to the left of the average curve usually indicate incomplete response to hardening.

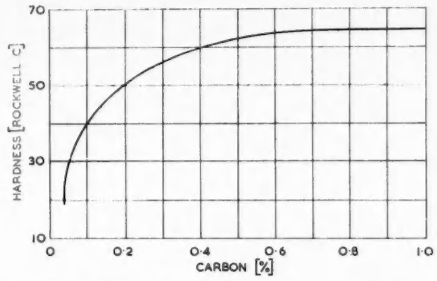


Fig. 3. **Dependence of maximum possible hardness on carbon content for plain carbon or low-alloy steels.**

martensitic, ferritic, and austenitic, respectively. Of these, the martensitic stainless steels are strengthened by usual heat-treating procedures. Ferritic stainless steels are not, and are normally used in the annealed state, where they exhibit their maximum corrosion resistance and ductility. Austenitic stainless steels, which are non-hardenable by heat treating, are appreciably strengthened by cold work (Fig. 4).

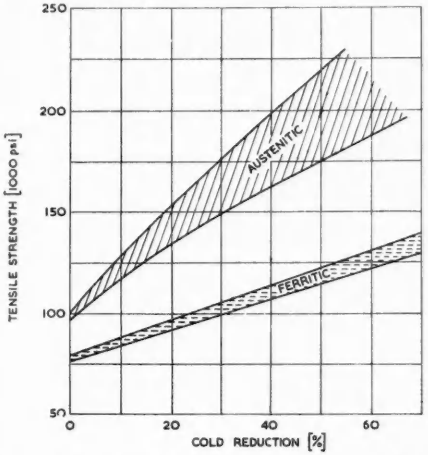


Fig. 4. **Effect of cold reduction on the strength of stainless steels.**

Also available are several special stainless steels which fall generally into the " austenitic " group, but which are precipitation hardening. Resembling types 301 to 304 in corrosion resistance, they offer equal or higher strengths when hardened.

WROUGHT ALUMINIUM ALLOYS.

Many of the aluminium alloys can be heat-treated to provide tensile strengths ranging from 1·8 to 2·7 times the annealed strength of the alloy. Like conventional steel heat treatment, solution heat treatment of aluminium alloys consists of raising the temperature of the alloy (910° to 1000° F), followed by a quench (usually in cold water for wrought alloys), which raises the strength to the desired level.

Following solution heat treatment, ageing is necessary to " precipitate out " soluble constituents. During the ageing or precipitation hardening treatment, the strength of the alloy increases to a maximum. Further ageing or over-ageing causes a decline in strength, until a fairly stable condition is reached.

In certain alloys—17S and 24S for example—precipitation hardening occurs at room temperature within a few days; consequently, these alloys are usually naturally aged. In others—11S, 14S, 18S, 25S, 32S, 51S, 61S, and 75S—years would be required. These alloys require artificial ageing—raising to a temperature of 250° to 275° F (for wrought alloys) for 4 to 10 hours.

MAGNESIUM, TITANIUM, AND NICKEL ALLOYS.

Various grades of magnesium, titanium, and nickel alloys can be heat treated, the treatment usually consisting of solution heat treatment and/or age (precipitation) hardening.

Magnesium alloys, for example, are usually solution heat treated with an air quench or further artificial ageing Some grades of titanium can be heat-treated by raising to temperature and air cooling (thin sections) or quenching (thick sections). In the case of titanium, however, present practice usually relies on cold working for strength increases.

Many different nickel alloys with widely varying compositions are available; consequently, heat treatment cannot be summarised for all. The softest form of K Monel is obtained by water quenching; heat treating, to obtain maximum properties, consists of a single age-hardening treatment followed by slow, controlled cooling. By contrast, Z nickel requires a solution heat treatment preceding the single precipitation hardening treatment. The best treatment for Inconel X is considered to be a solution heat treatment followed by both a high-temperature (1550° F) and low-temperature (1300° F) ageing treatment to develop the best combination of strength and ductility. Thus, each case must be individually evaluated.

COPPER ALLOYS.

Most copper alloys act like pure metal and cannot be heat-treated; cold work is used extensively for strengthening—either by drawing, forming or cold extruding.

Based on tensile strength, copper work-hardens at a rate of about 400 psi for each 1% of reduction in area by drawing, yellow brass at about 800 psi, silicon bronze at 1100 psi, and several of the aluminium bronzes at 1400 psi. Thus, the variation is quite wide.

Exceptions to the rule on heat treatment are several precipitation-hardening alloys, which can be strengthened by a solution heat-treatment and precipitation-hardening technique. These alloys are beryllium copper, nickel-beryllium copper, cobalt-beryllium copper, chromium copper, and nickel-phosphorus copper, most of which are 97% or more copper. In addition, several aluminium-bronze alloys, available principally as hot-forging alloys, can be heat-treated.

FERROUS CASTINGS.

The three broad groups of ferrous castings, i.e., cast iron, malleable iron, and cast steel, differ in their response to heat treatment, and should be considered separately :—

Cast Irons:—Cast irons suitable for heat treating have a graphite carbon content of between 2 and 3%, preferably of small particle size. Soft grey irons with coarse graphite and ferrite and high silicon do not improve in strength as much as lower-silicon pearlitic irons with smaller graphite particle size. Alloyed cast irons can often be quenched in an air blast or still air to secure the desired hardness; consequently, they may be used for more complicated shapes, where a more drastic oil quench employed for plain irons might be detrimental. For highest tensile properties and shock resistance, a tempering operation is included.

Actually, quenching from the usual temperatures of about 1500° F reduces the tensile strength below as-cast values, while hardness is increased (Fig. 5). Tempering raises tensile strength as the draw temperature increases, until a maximum strength, approximately equal to the as-cast strength, is reached. Beyond this tempering temperature, strength is again lower. At the tempering temperature producing maximum tensile strength, however, hardness remains substantially higher than original as-cast hardness.

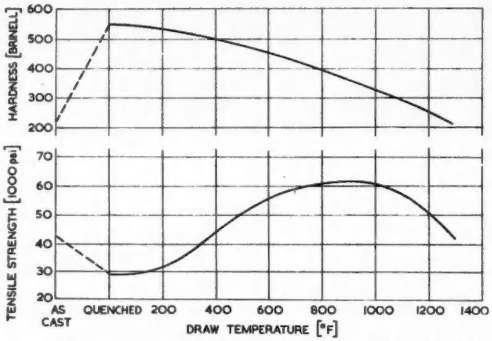


Fig. 5. **Average variation in the tensile strength and hardness of cast iron with draw temperature.**

Malleable Iron:—Standard malleable iron is used in the malleabilised or annealed condition, in which it exhibits its well known ductility and toughness. Exceptions are copper or copper-molybdenum alloyed malleable irons, which can be precipitation hardened. Pearlitic malleable irons, however, can be direct-hardened by an oil quench and drawn to any desired hardness, but response is slower than for steel. With most malleable irons, such heat treatments are employed for hardening, rather than for raising the strength level.

Cast Steels:—Heat treatments used for cast steels resemble those for wrought steel. Low-carbon (below 0·2%) steel castings do not respond readily to heat treatment, which is used only for annealing, refinement in grain size, and improvement in ductility. Medium-carbon steels, by contrast, are seldom used in the as-cast condition, improved tensile strength being obtained by an air quench, air quench and draw, or liquid quench and draw. High-carbon (above 0·4%) steel castings are usually quenched and drawn for applications requiring high strength and resistance to abrasion. Form cannot be too complex nor size too large, because of the danger of quench cracking.

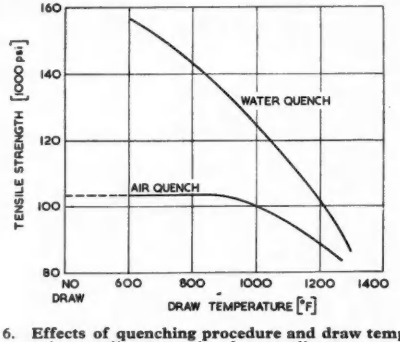


Fig. 6. **Effects of quenching procedure and draw temperature on the tensile strength of a medium manganese-molybdenum cast steel.**
Test castings were first heated to 1650° F.

Alloy cast steels, like wrought alloy steels, are designed to be heat-treated. Hundreds of different alloy combinations and heat-treatment schedules are available to bring out the best properties of the alloy steel. The effects of two different quenching procedures on the tensile strength of a medium manganese-molybdenum steel are shown as an example in Fig. 6.

NON-FERROUS CASTINGS.

Cast non-ferrous metals resemble their wrought counterparts in that solution heat treatment and precipitation-hardening methods are used for improving strength level. Thus, the copper alloys previously listed are capable of strength improvement as castings.

Many of the aluminium casting alloys are also capable of being heat-treated by the same procedures. For certain intricate castings, which cannot be quenched without causing quenching strains, a precipitation treatment only may be used. Magnesium-base alloys are similarly treated, solution heat treatment being used to increase tensile strength, percentage elongation, and toughness. Subsequent precipitation heat treatment or ageing increases yield strength and hardness, with decrease in percentage elongation and toughness.

PLASTICS.

The tensile-strength properties of plastics are extremely susceptible to many influences; consequently, the actual strength of a part may be quite different from property test values. Mould design and gating, amount of plasticiser or filler, and temperature all have a strong effect. For thermosetting compositions, polymerised during moulding, tensile strength is also dependent upon moulding technique.

Percentage of plasticiser—necessary to obtain proper flow during moulding for many plastics—alters physical properties. A highly plasticised, soft material, having easy moulding properties, has lower tensile strength than the same material in harder, less plasticised grades.

Fillers in small quantities do not appreciably affect tensile strength; when present in large proportions, they can either increase or decrease tensile strength. Cord, chopped fabric, glass fibres, and similar fibrous materials usually increase tensile strength. Granulated or powdered fillers, such as mineral flour, whiting, and diatomaceous earth, are usually added to change colouring or opacity, or to sharpen definition of moulded edges. Such fillers can decrease tensile strength, if present in sufficient quantity.

Temperature has a much greater effect on the strength of most plastics than on metals. Normal temperate-zone atmospheric temperature variations have but little effect on metals, whereas plastics are affected to a great degree. Humidity also plays a part, although atmospheric relative-humidity changes cause less significant differences.

Mould design, and particularly gating, alter actual strength. A moulded test bar, gated at the centre, rather than at one end, usually has significantly lower tensile strength. "Weld marks," where two flow channels in a moulded part meet, indicate areas of significantly lower strength, and tensile strength at right angles to highly directional flow lines is usually lower. Variations in density throughout the moulded part may cause weak points.

Adequate cure is essential in all thermosetting plastics, since strength is directly dependent upon polymerisation (formation of molecular chains) of the resin.

RUBBER AND ELASTOMERS.

The ultimate tensile strength or breaking strength of elastomeric materials usually has little practical significance, since such compositions may elongate 700% or more before breaking, whereas actual conditions may call for much less deflection. The usual practice for rubber, therefore, calls for the tensile strength properties to be stated as a percentage modulus (usually 300 or 400%), indicating the tensile stress at the stated percentage elongation.

Most rubber and elastomer parts are not used in tension, shear or compression being more usual. Tensile values are thus not too applicable. In addition, the relationship between tensile properties and other properties is rather haphazard, so that tensile properties are seldom related to serviceability. The main use of tensile tests is to estimate the deteriorating effects of heat, chemicals, etc. Variations in tensile strength are indicative of such changes.

Transient Processes in Contactless Magnetic Relays

By I. B. NEGNEVITZKYI and L. L. SAMURINA. (From *Elektrichestvo*, No. 4, April 1950, pp. 46-50, 9 illustrations, and No. 9, September 1953, pp. 64-69, 11 illustrations.)

In this article, the influence of a variety of circuit parameters on the time constants of a device known as a contactless magnetic relay is reported. The most favourable circuit is found to be that employing resilient feedback, which permits an arbitrary variation of the time constants, without affecting the sensitivity of the device.

UNDER certain conditions, a magnetic amplifier with a positive feedback operates as a relay and can be applied where a contactless relay is required. Such a relay may be called a " contactless magnetic relay."

Fig. 1 shows the simplest diagrammatic circuit of a magnetic amplifier with positive feedback. As shown, the load element Z_L is situated in the d.c. circuit but, without change in principle, the load element could also be situated before the rectifier, in the a.c. circuit.

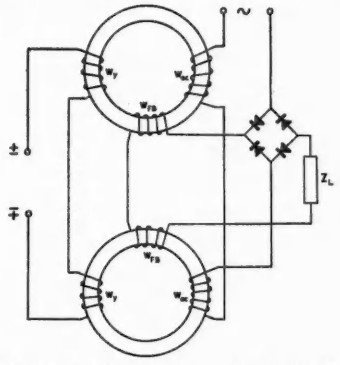


Fig. 1. **Basic circuit of magnetic amplifier with feedback loop.**
w_{ac} = a.c. winding; w_{FB} = feedback winding; w_y = control winding; Z_L = load.

At a definite ratio k_{FB} between the number of turns w_{FB} in the feedback winding and the number of turns w_{ac} in the a.c. winding, the characteristic curve of the amplifier assumes the form shown in Fig. 2, this graph being a plot of the load current I_L against the control current (signal) I_y. The presence of a loop in the characteristic curve and its nearly vertical branches are the distinguishing properties of the magnetic amplifier.

At zero signal, a large current (Fig. 2, point *B*) flows in the load. Positive signals do not cause any substantial variations in the load current (section *BA*). Negative signals, until point *D* is reached, reduce the load current very slightly. At a negative signal, corresponding to point *D*, the load current drops suddenly

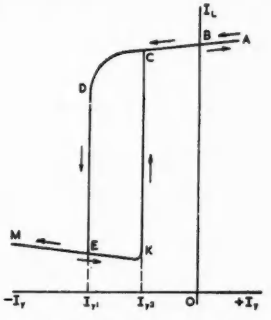


Fig. 2. **Characteristic curve of a magnetic amplifier with feedback, operating as a relay.**

(section *DE*). Further increase in the negative signal causes a gradual increase in I_L (section *EM*). If now the magnitude of the negative signal is gradually reduced, the load current I_L falls gradually (section *MK*) and, after passing a minimum, increases equally gradually. However, when the negative signal reaches point *K*, the current in the load suddenly jumps up (section *KC*).

It can be shown that, in order to obtain a relay characteristic, the above-mentioned ratio k_{FB} of numbers of turns, also known as the " feedback coefficient," must be larger than unity. This condition is necessary, but not sufficient; other conditions relating to the voltage and frequency of the a.c. supply and the resistance of the load element are not easily formulated in general terms, though all these factors determine whether or not the circuit operates as a relay.

The main advantage of the contactless magnetic relay is, of course, its lack of contacts and any other moving parts. Its main disadvantage is that the load current is never completely blocked or interrupted. Moreover, the circuit is sensitive to fluctuations in voltage, frequency, and temperature and to the resistance of the load element.

Additional advantages of the relay are the wide range of adjustment of properties by means of simple variations in the electrical design parameters of the circuit elements, and the facility with which the relay can be linked with other relays and circuit elements to achieve a variety of desired properties. This facility arises from the fact that the relay is a purely electrical circuit and needs electrical connections only.

For some functions of the relay, it is necessary to introduce an additional magnetising coil, known as the " shift winding." A direct current flowing through the shift winding corresponds to a constant positive signal and displaces the ordinate axis (axis of zero signal in the control winding) in Fig. 2 to the right. This shift can be so chosen that any desired value of the " release " or " blocking " current in the control winding can be achieved. In particular, it is possible to obtain a contactless magnetic relay operating like a contact relay with normally open contacts. In such a case, the line of zero signal must be shifted to the left until the loop of the relay characteristic is situated to the right of the zero signal axis.

The inertia properties of the magnetic amplifier cause the contactless magnetic relay to have, like a contact relay, a finite time delay between the appearance of a signal and the effective change of the load current. In practice, the problem of this delay, also known as the " release time " or the " blocking time," is naturally of the greatest importance. The peculiarity of the contactless magnetic relay is, of course, that it does not actually make or break the load circuit, but merely changes its current from a minimum to a maximum value and *vice versa*. The time of release and blocking in this relay must therefore be suitably formulated.

In an ordinary (electromagnetic) contact relay the total blocking (breaking) time is made up of the separate times for the rise of the control current to its tripping value and for the movement of the contacts. At the end of the blocking time, the contacts are separated and the current in a pure resistance load drops practically instantaneously. In a contactless magnetic relay, the load current changes simultaneously with the control current; consequently, even with a pure resistance

load, the load current changes progressively with time. The release or blocking time of the contactless magnetic relay can therefore be defined as the time interval during which the load current approaches its nominal value, within 5%. This interval starts at the instant when the control voltage is applied to the relay. Clearly, the release and blocking times are entirely determined by the transient processes in the relay circuit.

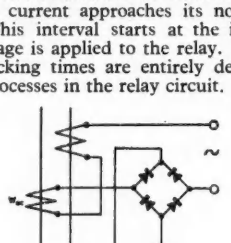


Fig. 3. **Basic circuit of a choke-type contactless magnetic relay.**

Fig. 3 shows the circuit of the simplest choke-type contactless magnetic relay. The delay in this relay depends on the transients, both in the d.c. circuits (control circuit and feedback circuit) and the a.c. circuit. Usually, however, the delay in the a.c. circuit is relatively small and the blocking and release times depend substantially on the duration of the variation in the constant component of the magnetic flux.

The control circuit is a closed loop, which resists the change of current in the feedback winding w_{FB} and therefore in the load R_L. The feedback connection, the load, and the rectifier constitute, under certain conditions, a closed circuit magnetically linked with the control circuit and so resist the change in the control current. However, under normal conditions of operation of a contactless magnetic relay, the latter linkage is of little significance and it can be said that the windings w_y and w_{FB} are related through a unilateral inductive linkage only.

The case of a parallel connection of the a.c. coils w_{ac} which raises the inertia of the magnetic relay, is not considered here. The influence of eddy currents and hysteresis can usually be neglected.

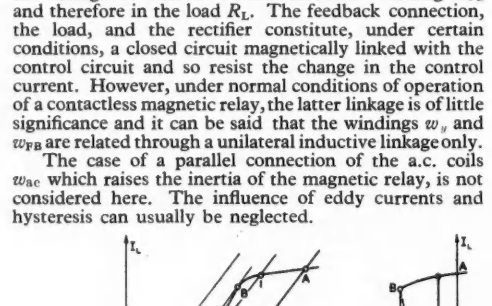


Fig. 4. **Characteristic curves.**

(a) Magnetic amplifier without feedback.
Curve *ABCD*: without feedback.
Line *OA*: Characteristic of feedback.
(b) Static characteristics of choke-type contactless magnetic relay.

Now consider the sequence of the blocking process in a choke-type magnetic relay. In Fig. 4(a) (curve *ABCD*), the relation of the load current and the resultant constant component of the m.m.f. is shown, $F_{RES} = F_{FB} + F_y$, F_y being the m.m.f. of an amplifier without feedback. The operating point of the amplifier with feedback is determined by the intersection of the curve *ABCD* with the characteristic curve $F_{FB} = f(I_{acm})$, whose shift corresponds to the control current I_y.

I_{acm} is the r.m.s. value of the a.c. current, which, with an ideal rectifier and a pure resistance load, is equal to the load current I_L.

At $I_y = 0$, the operating point is *A*. The load current is I_{LA}. When a voltage which, in the steady state, sets up the control m.m.f. F_y, is applied to the input of the relay, the current i_y (F_y) begins to rise, the straight line *OA* is shifted to the left and the operating point is displaced along the section *AB* of the curve *ABCD*. Over this section, the current i_L changes relatively little and the influence of its variation upon the current i_y is also comparatively small. Beyond point *B*, which, in the static characteristic curve of the relay, shown in Fig. 4 (b), is the beginning of the sudden drop in current i_L, the current i_L, and hence also the constant component of the magnetic flux, tend to change sharply. However, in this process the control circuit experiences and e.m.f. and an additional component appears in the current which resists the change of the constant magnetic flux Φ_{dc}. Consequently, the current i_y in the control circuit is, as it were, composed of two currents, i.e., the current i_y', which is caused by the e.m.f. E_y applied to the control circuit, and the current i_y'', which is caused by the change of the flux Φ_{dc}, mainly owing to a change of current i_L. The current i_y' tends to cause the blocking of the relay, i.e., a reduction in the current i_L, and this is resisted by the current i_y'' ($i_y = i_y' - i_y''$).

In the lower part of the curve *ABCD* in Fig. 4 (a), the current i_L and the flux Φ_{dc} change very little, and therefore i_y'' falls and vanishes at the end of the transient processes, whilst the operating point is determined by the steady-state value of the controlling m.m.f. F_y (point *D*, Fig. 4 (a)). Hence, in the movement of the operating point along the sections *AB* and *CD* in Fig. 4 (a), the influence of the current i_y'' is small, whilst along the section *BC* the current i_y'' has a strong retarding influence. Hence, the main part of the blocking period is taken up by the time it takes the current I_L to change from the value I_{LB} to the value I_{LC}.

On the basis of the foregoing discussion, the influence of various parameters of the relay on the duration of the transient process can be clarified, as follows :—

Influence of the resistance in the control circuit.

With a rise in the resistance R_y in the control circuit, other things being equal, the current i_y' rises more quickly, and the counteracting current falls more quickly. Naturally, therefore, with an increase in R_y, both the blocking and release times are reduced. It is assumed that the fall in the current I_y down to vanishing point is accomplished without actual interruption of the control circuit.

Influence of the number of turns of the control winding.

With an increase in w_y, other things being equal, apart from an increase of the time constant of the control circuit proper, the e.m.f. excited in the winding w_y by the variation of i_L also increases and so, too, does the current i_y'' counteracting the blocking or release of the relay. With an increase in the number of turns w_y, the retarding influence of the control circuit, which constitutes a closed loop in relation to the feedback circuit containing w_{FB}, is increased, and hence the blocking or release times are lengthened.

Influence of the reserve coefficient of blocking current.

The reserve coefficient k_R of blocking current may be defined as the ratio of the steady-state value of the control current to its value after blocking.

$$k_R = \frac{I_y}{I_{y\,BL}} = \frac{F_y}{F_{BL}}$$

The larger the value of k_R, the more rapidly the current i_y' reaches the value of the blocking current, and the influence of the current i_y'' is relatively reduced. Consequently, with an increase in k_R, the transient process is accelerated and the blocking time t_{BL} is reduced. The influence of a change in the coefficient k_R on the release time t_{RE} is, however, different. With an increase in k_R, i.e., in the m.m.f. F_y, k_R' decreases and tends to unity. The release time goes up in this process.

INFLUENCE OF SHIFT.

The introduction of a positive shift displaces the loop of the characteristic curve in Fig. 4 (b) to the left and, with an unchanged difference $(F_y - F_{BL})$, the blocking time t_{BL} rises slightly and the release time t_{RE} falls sharply. If the coefficient k_R is held constant whilst increasing the shift, the time t_{RE} changes less, whilst the time t_{BL} remains constant.

INFLUENCE OF THE FEEDBACK COEFFICIENT k_{FB}.

If the feedback line (straight line OA, Fig. 4 (a)), is shifted so that the operating point becomes point 2, this state of operation is unstable and after any external disturbance the operating point will shift to points (1) or (3). All points with a positive angle β, equal to the difference between the slope α_1 of the characteristic curve of the magnetic amplifier without feedback and the slope α_2 of a direct feedback, will be unstable. In fact, the magnitude of the angle β measures the degree of instability. The larger the value of β, the less stable is the section BC of the characteristic curve of the amplifier and, consequently, the more rapidly will the operating point shift to a stable point (1 or 3). When the relay operates in blocking, its control circuit is fed with the e.m.f. E_y, which ensures the shift of the working point in the direction of point (3), rather than point (1).

As shown above, the interval in which the current I_L changes from I_{LB} to I_{LC} (Fig. 4 (b), constitutes the major part of the blocking time. Therefore, with a constant reserve coefficient of blocking current and with other parameters unchanged, an increase in k_{FB} (i.e., the angle β) reduces the total blocking or release time, and *vice versa*. This dependence is strongest at small control circuit resistances R_y; otherwise, the influence of the loop containing w_{FB} is altogether small.

It is interesting to note that, in the magnetic amplifier with positive feedback operating as a relay, the time constant of the amplifier rises with an increase in k_{FB} (since in this case the angle β is reduced). The transient process will last longest in the " critical " state, i.e., at the boundary between the operation as a linear amplifier and operation as a relay.

The simplified qualitative discussion given here does not deal with all the phenomena taking place in this circuit. The theoretical analysis and numerical calculations are complicated, primarily because the static characteristics of the amplifier without feedback and the static characteristics of the feedback differ from the dynamic characteristics. Thus, in Fig. 5, curve (1) represents the relation $I_L = f(I_y)$ at $R_y = 17$ ohms as determined from oscillograph records, while curve (2) is the same relation determined from the static characteristics of the amplifier and the feedback circuit. At $R_y = 650$ ohms, curves (3) and (4) show an even larger difference between the static and dynamic characteristics.

METHODS FOR CHANGING THE OPENING TIMES OF THE CONTACTLESS MAGNETIC RELAY.

The preceding discussion points to certain methods for modifying t_{BL} and t_{RE}. For instance, to reduce t_{BL}, an additional resistance can be introduced into the control circuit. If a capacitance is switched in parallel with this resistance (differentiating loop), it is possible to reduce

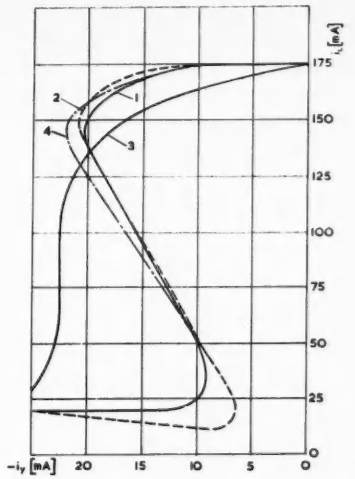


Fig. 5. **Dynamic and static characteristic curves of a contactless magnetic relay.**
(1) Dynamic, at $R_y = 17$ ohms.
(2) Static, at $R_y = 17$ ohms.
(3) Dynamic, at $R_y = 650$ ohms.
(4) Static, at $R_y = 650$ ohms.

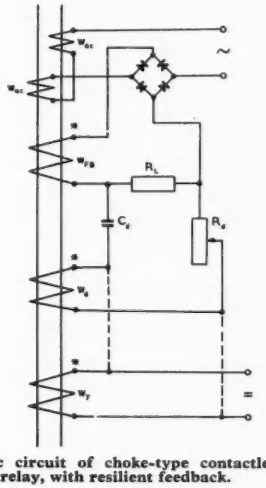


Fig. 6. **Basic circuit of choke-type contactless magnetic relay, with resilient feedback.**

t_{BL} still further. Generally, every known electrical method for modifying t_{BL}, used in ordinary contact relays, can also be applied to the contactless magnetic relay. Moreover, t_{BL} and t_{RE} can be altered by varying k_{FB} or the amount of shift.

Most of the methods for changing t_{BL} and t_{RE} indicated above are associated with additional power consumption in the control circuit. Thus, the sensitivity of the relay is reduced. In contactless magnetic relays there is another method for modifying t_{BL} and t_{RE}, and this consists of the introduction of a so-called internal resilient feedback. This can be embodied by means of a transformer and a condenser.

The signal for the resilient feedback can be fed either into a separate winding w_d in the relay (Fig. 6) or into the control winding w_y, as shown by the broken line in Fig. 6. In the absence of a controlling signal, the voltages across the load R_L and the condenser C_d are equal and both are at their peak. The constant component of the current in

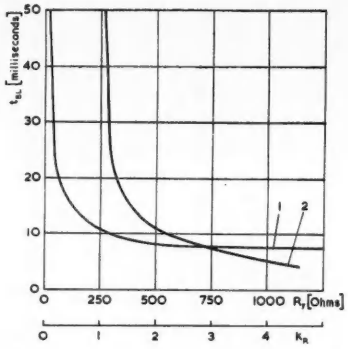


Fig. 7. **Blocking time as a function of R_y (curve 1) and k_R (curve 2).**
Curve (1): With $k_{FB} = 1{\cdot}14$ and $k_R = 1{\cdot}2$.
Curve (2): With $k_{FB} = 1{\cdot}14$ and $R_y = 43$ ohms.

the resilient feedback circuit is zero. With the appearance of the controlling signal, the voltage across the load will fall, causing a discharge of the condenser. The resulting discharge current i_d of the condenser will, according to whether it flows with or against the current i_{wy}, cause an acceleration or retardation of the blocking of the relay.

Modification of the parameters of the resilient feedback loop (R_d, C_d, and w_d) can achieve a wide variation of the blocking and release times of the relay. The circuit shown in Fig. 6 is designed to accelerate the blocking time.

If the feedback signal is fed into the control winding w_y, the power in the control circuit, and therefore the sensitivity of the relay, remain unchanged. The introduction of resilient feedback by means of a differential-circuit transformer can be similarly embodied. Resilient feed back can also be introduced through an intermediate amplifier. In contact relays it is clearly impossible to use a feedback of this type.

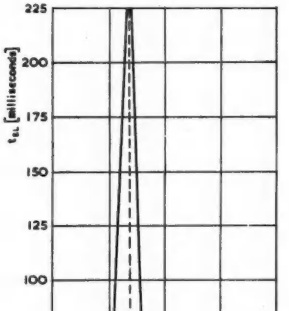


Fig. 8. **Dependence of t_{BL} on k_{FB}, with different values of R_y.**
Curve (1): $R_y = 250$ ohms.
Curve (2): $R_y = 1000$ ohms.
The broken line shows the limit of relay operation.

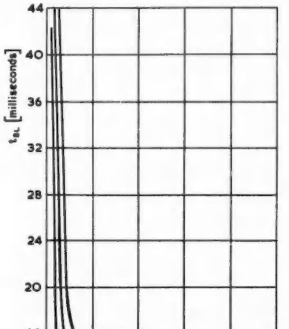


Fig. 9. **Graph representing t_{BL} as a function of P_y, with $k_{FB} = 1{\cdot}14$.**
Curve (1): Varying R_y, with $k_R = 1{\cdot}2$.
Curve (2): Varying k_R, with $R_y = 43$ ohms.
Curve (3): Introduction of different resistances into the w_y circuit, bridged by a capacitance of 200 μF.

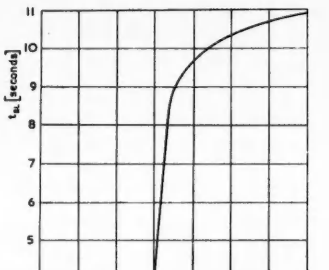


Fig. 10. **Dependence of t_{BL} on C_d, with introduction of resilient feedback arranged for retardation of blocking.**
$R_y = 17$ ohms; $k_{FB} = 1{\cdot}14$; $k_R = 1{\cdot}2$.

RESULTS OF EXPERIMENTAL STUDIES.

The relay was assembled on toroidal Permalloy cores of 42 mm outer diameter, 30 mm inner diameter, and 3 mm pack thickness. The numbers of turns of the different coils were as follows :— $w_{ac} = 280$, $w_{FB} = 320$ with several tappings, $w_y = 290$, and $w_d = 270$. The purely active load had a resistance of $R_L = 50$ ohms. The supply voltage $U_{ac} = 15$ volts at 400 cycles. The current in the load during the blocking of the relay changed from 175 mA to 20 mA.

Fig. 7 shows the blocking time as a function of R_y (or of k_R), while Fig. 8 shows the dependence of t_{BL} on k_{FB} at different values of R_y. In this figure the vertical broken line represents the same dependence for $k_{FB} < 1{\cdot}018$, which is equivalent to the state of operation as a linear amplifier.

It is interesting to compare, by means of the control power consumed, the effectiveness of different methods for the reduction of t_{BL}. In Fig. 9 the family of curves $t_{BL} = f(P_y)$ gives the blocking time as a function of input power with various devices employed for a reduction of the blocking time. On the other hand, Fig. 10 shows the dependence of t_{BL} on C_d at $w_d = 270$, when the resilient feedback is used for a retardation of blocking. The latter device, when used for an acceleration of the blocking time, yields a minimum at $k_{FB} = 1{\cdot}035$, $R_y = 43$ ohms and $k_R = 1{\cdot}2$. This minimum was about 60 milliseconds. A reduction in the blocking time, by insertion of an additional resistance bridged by a capacitance in the circuit, would have led to a rise in the input power to almost twice its former value. The duration of the transient process in magnetic amplifiers and contactless magnetic relays can also be reduced by raising the frequency of the supply.

Characteristics and Control of Electrostatic Generators

By N. FELICI. (From *Bulletin de la Société Française des Électriciens*, Series 7, Vol. 3, No. 36, December 1953, pp. 771-777, 9 illustrations.)

THE study of the characteristics of electrostatic generators is of interest not only because it is necessary to know the behaviour of this type of generator in practical applications, but also because, in spite of the considerable differences between electrostatic and electromagnetic machines, both types show a remarkable analogy resulting from the "principle of reciprocity," which facilitates the understanding of their theory and practice.

The electrostatic generator which serves as a basis for the following considerations can be represented simply as a mechanical "charge elevator," in which the moving parts, or carriers, which may be either conductors or non-conductors, move physically between two points of different potentials (Fig. 1). At one of these points, or poles, the carriers are connected to earth by a convenient arrangement and given a positive charge by influence from an assumed inductor, which itself is maintained at the negative potential $-V_e$, the excitation voltage. Subsequently, the earth connection is broken and the carrier carries its positive charge to the other pole at the output voltage $+V_d$; there the charge is given up, the carrier is again connected to earth, recharged, etc. Throughout the following considerations, it is assumed that only the method of charging by influence is used, as other methods, such as, for instance, friction, are of little practical interest; nor is mention made of machines with two carriers moving in opposite directions, as their discussion does not affect the final conclusion.

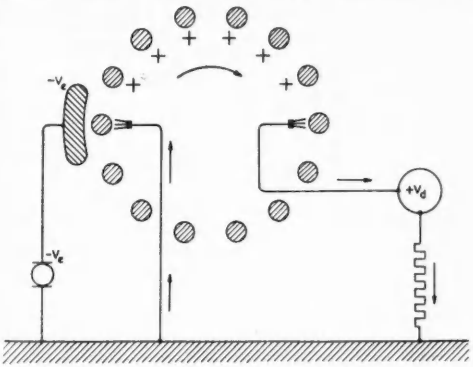


Fig. 1. **Schematic representation of electrostatic generator.**

The electrostatic generator thus appears as a mechanical elevator, a kind of chain pump, the buckets of which, represented by the carriers, fill up with electricity by influence, increase the potential of this electricity from zero to V_d, discharge it into a collector, fill up again, and so on. Of course, the electricity yielded by the carrier to the pole of potential V_d flows back to earth after giving up its energy to the collector. The circuit is thus closed, as it must be in any d.c. system; however, in one section of this circuit (the generator), the flow of electricity takes place by convection and not by conduction, and this is a distinctive feature of electrostatic machines.

From the foregoing and the laws concerning condensers, it follows directly that the charge taken on by a carrier, and hence the output current I, are proportional to the excitation voltage $-V_e$. Thus, $I = AV_e$, where A is a coefficient proportional to the speed of rotation. In the following, this speed is assumed to be constant, as almost always it is in practice.

It will be seen that, as a first approximation, the current I is determined by V_e and not by V_d, i.e., that the electrostatic machine is by nature a constant-current generator, a fact which constitutes an essential difference between it and electromagnetic machines. This statement, however, is accurate only on the assumption that the carriers give up their entire charge to the appropriate pole, but this is not strictly the case.

When the carriers make contact with the pole, they cannot, in practice, be prevented from establishing, at the same time, some lines of force to earth, where the potential is zero, or to the inductor, where the potential is $-V_e$. As a result, the carriers always retain a certain positive charge, the magnitude of which is a linear function of V_e and V_d, and which, in fact, constitutes a loss as regards the external circuit. Although the charges retained through these strong capacities can be kept small by appropriate design of the machine, they cannot be eliminated altogether. Consequently, the characteristic of such a machine cannot be expressed by the single formula $I = AV_e$, but only by the formula

$$I = AV_e - BV_d \quad .. \quad .. \quad (1)$$

where B is a positive coefficient and also a function of the speed of rotation. In a machine reasonably well designed for producing energy, B is very small in relation to A.

APPLICATION OF THE "PRINCIPLE OF RECIPROCITY"

The characteristic expressed by the above equation is quite different from that of electromagnetic machines, which are generators with almost constant voltage. It is, however, possible to reduce the characteristics of both types to a common basis by a transformation known as the "principle of reciprocity." In fact, the characteristic of an electromagnetic d.c. machine can be expressed by

$$V = AI_e - BI_d$$

where V is the voltage at the terminals, I the field current, and I_d the output current. According to the principle of reciprocity, this and the previous equation correspond to each other exactly:—The current supplied by the electrostatic machine corresponds to the voltage of the electromagnetic machine; the excitation voltage of the electrostatic machine corresponds to the field current of the electromagnetic machine; the loss of current caused by the output voltage of the electrostatic machine corresponds to the voltage drop caused by the output current of the electromagnetic machine; finally, the coefficients A and B, which in the electrostatic machine are of the nature of conductances proportional to the speed, are in electromagnetic machines equivalent to resistances (or rather impedances) equally proportional to the speed. These parallels clearly illustrate the principle of reciprocity.

It might be said, in the case of the electromagnetic machine, that the coefficient B is determined by the magnetic flux as well as by the ohmic resistance of the armature, whilst in the case of the electrostatic machine B is in practice entirely determined by capacities and the stray flux created by the output voltage. However, if the electrostatic armature is not perfectly insulated, and if it possesses even a small conductance, the latter causes a certain loss of current, which is proportional to V_d, just as the resistance in the electromagnetic case causes a voltage drop proportional to I_d.

In addition, a slight difficulty may appear to arise in establishing a parallel with regard to the direction of the main and stray fluxes in both types of machines, these fluxes being largely parallel in the case of the electrostatic machine, whilst in the electromagnetic machine they form a right angle. This apparent paradox can, however, be explained by the positions of the brushes

in both types of machines, as these do not conform to the principle of reciprocity ; on the contrary, a point of contact in the electrostatic machine corresponds to a non-contact point in the electromagnetic machine and *vice versa*.

The testing of an electrostatic generator corresponds exactly to that of an electromagnetic machine on the basis of the principle of reciprocity. When testing an electromagnetic generator, it is the usual practice to run it on no-load, i.e., on open circuit, and to measure the corresponding voltage, by means of a voltmeter connected across the terminals, as a function of the exciting current. The machine is then put on load by connecting a gradually increasing conductance across the two terminals, and the voltage drop due to the armature reaction and resistance is measured as a function of the increasing current.

When testing an electrostatic generator, the terminals are first short-circuited by an ammeter and the short-circuit current is measured as a function of the excitation voltage. The resistance connected across the terminals is then steadily increased, whilst the current, which is decreasing at the same time, owing to the stray capacities (and, where applicable, to the armature conductance), is measured as a function of the increasing output voltage.

Maximum Constant-Field Characteristics

A physical fact, peculiar to electrostatics, is the strict limitation of the field intensity which an insulator can withstand. All electrostatic machines assume the existence of an ambient dielectric fluid. When the field strength in any point exceeds the limit allowed by this medium under the given conditions, normal functioning of the machine is possible either to a limited extent only, or not at all. It is of interest to consider the most unfavourable point of the machine. Here, the field can be expressed by :—

$$E = CV_e + DV_d \quad . . \quad . . \quad . . \quad (2)$$

If maximum performance is required in every case, it is necessary to equate the field strength with the critical value E_m for the particular operating conditions. From eqs. (1) and (2) can be derived a new relation between I and V_d, representing the maximum performance characteristic which indicates the maximum current the machine can yield at the given speed, for any given output voltage,

$$I = AE_m/C - (B + AD/C)\,V_d \quad . . \quad (3)$$

It will be seen that the maximum performance characteristic begins with the same short-circuit current as the constant-excitation characteristic, but that the decrease becomes increasingly more rapid ; the difference can be very considerable and depends on the design.

Until now, no clear distinction has ever been made between the constant-excitation and the maximum constant-field characteristics. This has led to serious errors in the assessment of the performance of many electrostatic machines and also to completely erroneous ideas concerning their capabilities. The clearest example is that of the Van de Graaff generator.

In this generator, charging and discharging of the carrier takes place inside practically closed equipotential spaces, under such conditions that the term $-BV_d$ is virtually negligible. From this it has been generally deduced that the output current should be independent of the output voltage ; this, however, conflicts with experience, the drop in I being frequently considerable. This is due to the fact that, in practice, the maximum constant-field characteristic is observed. Although B is zero, D is not zero. Between the poles, the field produced by the density of the charge carried by the belt (the term CV_e) and the field created by the output voltage (term DV_d) largely overlap. Every increase in V_d produces an ionisation which reduces the density carried.

Modifications of the Characteristic

The characteristic previously discussed relates to constant excitation. As in the case of electromagnetic machines, it is also possible to obtain an infinite number of other characteristics by replacing the relation V_e = constant by any function $f(V_e, V_d) = 0$, i.e., by making the output voltage react on the excitation.

Whilst a complete study of the possibilities the above opens up is of little practical importance, some cases are of interest, one of these being the linear characteristic passing through the origin, or " series characteristic." This characteristic is obtained by making the ratio V_d/V_e constant. In consequence, the ratio I/V_d is also constant and the characteristic will be a straight line through the origin, in the plane I, V_d. This can be achieved quite simply. Assuming that the voltage $-V_e$ is supplied by an electrostatic exciter, which itself is excited from the main generator (Fig. 2), and, furthermore, that the current produced by this exciter is made to flow through an ohmic resistance R which may be considered infinite, then :—

$I = AV_e - BV_d$ for the main generator, and

$I_e = A'V_d - B'V_e = V_e/R$ for the exciter.

Consequently,

$$I = V_d\left[\frac{AA'}{1/R + B'} - B\right] \quad . . \quad . . \quad (4)$$

It is possible to make R infinite if B' is sufficiently great, i.e., if the stray capacitances of the exciter are sufficiently high, and this presents no difficulties. The corresponding arrangement is very simple and requires no regulating system. As a group, the two machines are self-exciting, if conducting carriers and friction brushes are used, as accidental potential differences on metal contacts are always sufficient to initiate the process.

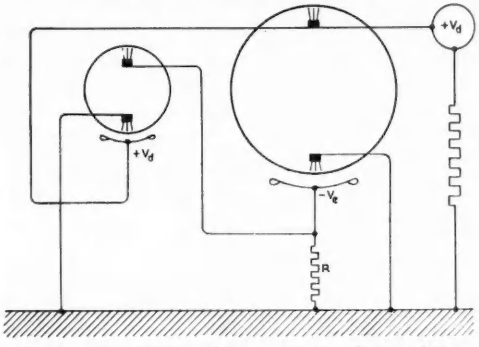


Fig. 2. **Arrangement giving a series characteristic.**

As in the case of series-wound electromagnetic generators, where self-excitation does not occur unless the resistance is below a certain value, self-excitation of the electrostatic generator with series characteristic occurs only when the conductance is below a certain limit, which in fact is equal to I/V_d. If, therefore, the set is operated on short-circuit or is connected to too low a resistance, it will not be self-exciting and will supply no current ; on open-circuit operation, or if connected to a very high resistance, the voltage increases rapidly until it is limited by either internal or external flash-over. Those who are not sufficiently well acquainted with the question of characteristics are likely to consider the behaviour of the machine irregular, to say the least. It is, however, easy to achieve perfectly stable operation by inserting in the generator circuit an adjustable point-to-plate discharge gap, the non-ohmic characteristic of which combines very favourably with that of the set.

The series generator has not been very well received, and it became necessary, therefore, to change the charac-

teristic, so as to obtain an almost constant voltage. Apart from these considerations, the constant-voltage characteristic also has the advantage in the case of applications where a series characteristic could be used (spraying, precipitators, etc.) of being unable to produce dangerous over-voltages. Furthermore, for feeding electronic valves, constant voltage is indispensable, and it may be said that to-day practically all commercial electrostatic generators are required to provide adjustable constant voltage.

This can be easily achieved by applying the previously mentioned principle, i.e., by making the output voltage react on the excitation. When the output voltage tends to increase, owing to a reduction of load, excitation voltage must be rapidly reduced, even to the extent, if necessary, of making output current zero. This result can be obtained simply by the use of discharge gaps. If a point-to-plate discharge gap, in air at either atmospheric or higher pressure, is inserted in the circuit carrying a current of the order of 10 to 100 μA, a stable potential difference between the point and the plate is obtained, particularly when the point is negative. What happens is that current impulses flow intermittently at a very high frequency, but the amount of electricity carried by each impulse is so small that the potentials are not affected and no radio interference is caused ; otherwise, the potential difference depends on the current to a small degree only, and is mainly determined by the geometrical arrangement of the electrodes, and the nature and pressure of the gas.

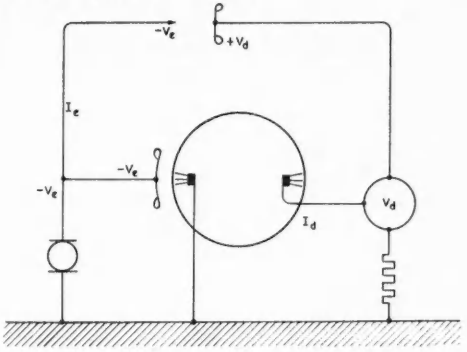


Fig. 3. **Arrangement giving a shunt characteristic.**

Assuming, therefore, that an exciter (electrostatic, for example) supplies an almost constant current I_e, the current required for maintaining the excitation voltage is practically zero (of the order of one micro-ampere at the most). The current I_e will thus be fed into a point-to-plate discharge gap, one electrode of which is connected to the insulated pole V_d and the other to the inductor $-V_e$ (Fig. 3). As I_e is quasi-constant and as the potential difference across the discharge gap depends only to a small degree on the current, $V_d + V_e$ will remain constant.

This can be illustrated by the following practical example for a normal output of 1 mA at 150 kV, with an excitation voltage of -30 kV. The current drops to zero when the excitation voltage is reduced to -15 kV ; when the discharge is set for 180 kV, the output current is 1 mA at 150 kV, and 0 mA at 165 kV. This is most satisfactory, the voltage drop being only 10% for an increase of current from zero to maximum. The machine thus has a shunt characteristic. Of course, the voltage drop is not caused in any way by any " internal resistance," but by the manner in which the reaction of the output and the excitation voltages is produced, making it possible to reduce this voltage drop even further, or to eliminate it altogether.

When the generator is made to supply a current in excess of normal, a point may be reached where the shunt characteristic intersects with the maximum output characteristic, and it is this latter characteristic which then becomes effective. When operating on this branch, the voltage will drop very rapidly, whilst the current will increase only very slightly, until it reaches the maximum short-circuit value. The complete characteristic of the generator, therefore, consists of two sections, both being straight lines. If the output voltage is plotted as the ordinate and the current as the abscissa, the first section of the characteristic will be nearly horizontal and the second nearly vertical, the first corresponding to the almost constant voltage and the second to the almost constant current. This combined characteristic is obviously very convenient for almost any application, providing all the advantages of a source of constant voltage and automatically limiting the current, without the need for protective arrangements, thus eliminating all danger to operating staff or equipment.

The voltage is very easily regulated by varying the size of the discharge gap, which alters the value of $V_d + V_e$, and shifts the entire shunt characteristic parallel to itself. However, if a rigidly constant voltage is required to be completely independent of the output current up to its maximum value, the foregoing arrangement must be modified.

One solution consists of employing an exciter, the current I_e of which increases equally with the excitation voltage $-V_e$; this can be achieved, for instance, by using as exciter a set of two machines with series characteristics. When the excitation voltage increases, so does the voltage $V_d + V_e$ across the electrodes of the discharge gap, owing to the increase of the current I_e across the gap. It is easy to regulate the exciters in such a way that this increase is exactly equal to the variation in the excitation voltage (15 kV in the preceding example). The output then remains absolutely constant. Instead of adjusting the characteristic of the exciter to obtain the required result, it is possible to use an exciter with over-compensation, i.e., one whose current increases more rapidly than required for the desired result ; under such conditions the output voltage of the main generator increases with the current ; to avoid this, it is sufficient to connect an appropriately calibrated ohmic resistance in series with the discharge gap.

Another method consists of influencing the behaviour of the discharge. The sum of the two voltages applied to the electrodes is constant, provided no third electrode is present, i.e., when the discharge is effected in the open, in which case the lines of force will be as shown in Fig. 4.

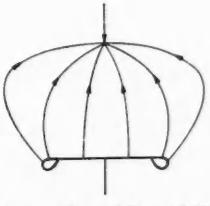


Fig. 4. **Lines of force of discharge in open air.**

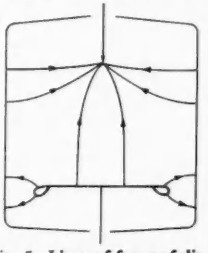


Fig. 5. **Lines of force of discharge inside a hollow conductor.**

In practice, the discharge is enclosed in a tight metal box, not only for reasons of protection but also to allow it to be operated under pressure and to reduce its dimensions. The lines of force in this case are as shown in Fig. 5. This metal box is usually earthed and acts as a third electrode ; as a result, the influence of the point electrode on the plate electrode is reduced. When the output voltage of the main machine is negative, as is most frequently the case, the box has the effect of reducing any variations in the plate potential (which ordinarily

(*Concluded on page* 156)

Tooling Problems with Ultrafine-Pitch Gears

By L. D. MARTIN. (From *The Tool Engineer*, Vol. 32, No. 1, January 1954; pp. 45-51, 8 illustrations.)

Some important tooling considerations, often overlooked in instrument gearing, are described in this article, which points out that, if the present trend of specifying ultrafine pitches continues, tool procurement problems may be seriously complicated.

THE tendency towards the increasing use of instrument gears with finer pitches than ever before is alarming many tool and gear engineers. While 100 diametral pitch was considered very fine a few years ago, there are now many applications requiring gears of 160 diametral pitch and finer. Indications point toward an increasing tendency to specify even finer pitches.

The law of diminishing returns sets up a practical barrier for pitch size, beyond which greater sacrifices in quality are required than the gains in satisfying space restrictions could offset.

The design engineer justifies the use of a certain pitch, regardless of its size, on the space restrictions with which he must cope. In doing so, he often overlooks the risks taken in loss of accuracy and increased tooling difficulties. Probably, all the ramifications of tooling, such as its procurement, manufacture, and limited sources of supply, are not generally understood. When design engineers are familiar with existing standards for fine-pitch gears, they take advantage of the smaller pinions recommended for special cases. This enables them to meet ratio and space requirements without resorting to ultrafine pitches which present tooling and measuring problems.

Since the accuracy of gears is dependent, to a large extent, on the accuracy which can be built into the tooling, it may be useful to examine the relative accuracy that can be produced in gear cutters of different pitches. For the purpose of comparison, hobs and gear shaper cutters of three diametral pitches, namely: 20 D.P. (the coarsest in the fine-pitch series), 100 D.P., and 160 D.P. have been chosen.

DIMENSIONS

Relative sizes of hob teeth for these three pitches are shown in Fig. 1. The point width of a 20-pitch, 20-deg pressure angle hob for producing gears in accordance with American standards for a 20-deg involute fine-pitch system is 0·0334 inch. That of a 100-pitch hob is 0·0055 in., while that of a 160-pitch hob is only 0·0029 in. These figures are for standard ground hobs with sharp corners. It happens that there are probably not more than two sources in the U.S.A. for ground hobs finer than 64 diametral pitch. If the 160-pitch hob is not ground, the chances are that the point-width will be even less than the 0·0029 in. shown in Fig. 1, owing to rounding-off of the tips during the hardening process.

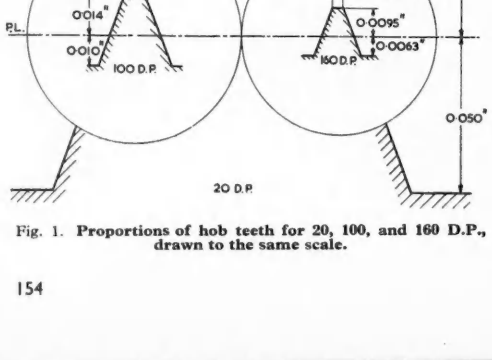


Fig. 1. **Proportions of hob teeth for 20, 100, and 160 D.P., drawn to the same scale.**

Many instrument gears are made of stainless and alloy steels. Hobs with only a 0·003-in. point width cannot last long when cutting gears of materials with relatively poor machinability. In practice, the point on the leading edge of the hob soon breaks down when cutting hard materials. When this happens, a high fillet is generated at the foot of the gear, which disturbs conjugate action and causes fillet interference, as shown in Fig. 2.

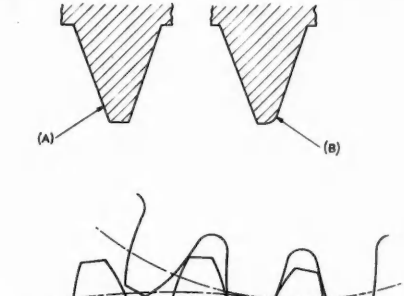


Fig. 2. **Fillet interference caused by worn hob.**
(A) New hob tooth with sharp corners.
(B) Hob tooth with 0·002 in. edge fillet on leading edge.
(C) Fillet interference in mating gears.

The point width of a 100-pitch hob is nearly twice as great as that of the 160-pitch hob. When proper precautions are taken to keep 100-pitch hobs sharp, satisfactory production can be obtained.

Fine-pitch hobs are ground with a double-conical grinding wheel. The relative point widths of grinding wheels for hobs of 20, 100 and 160 pitch are 0·042 in., 0·008 in., and 0·005 in. respectively. In the case of 160 pitch, this narrow point width results in wheel spring during the grinding operation. Aggravated by the speed of the hob-grinding machine back-off mechanism and by the intermittent grinding action introduced by the hob gashes, the wheel flexes slightly when it comes into contact with the hob flutes. The amount of flexure is dependent on wheel rigidity and the amount of stock removed. The wheel may bend slightly more on one flute than on another, depending on rigidity and repeatability of the back-off mechanism. This is why lead error tolerance is not diminished as the pitch becomes finer. Increased wheel flexure offsets the effects of the smaller pitch increment.

The Metal-Cutting Tool Institute's tolerance on lead variation tooth-to-tooth, is 0·0002 in., regardless of pitch, while the lead variation in total indicator variation for one turn is 0·0004 in. at 20 to 29 D.P. and 0·0003 in. on all pitches finer than 29 D.P. This disproportion of tolerance shows how the law of diminishing returns asserts itself because of practical considerations. At 20 pitch, a 0·0004 in. tolerance on lead means 0·25% lengthening or shortening of the linear pitch. At 100 pitch, the 0·0003 lead error is equivalent to a change of 0·95%, and, at 160 pitch, to a change of 1·53%.

Lead error in a single-threaded hob results in

profile error. In a multiple-threaded hob, lead error may result in spacing error, as well as profile error, if the hob flutes are not equally spaced.

Relative pressure-angle changes resulting from tolerance for hobs of the three selected pitches are shown in Fig. 3. The linear deviation from the theoretical shape shown is ± 0·0002 in. The profile can be on line *B-O*, *A-O*, or *C-O*. Since this is a linear increment, the equivalent angular deviation is proportionately greater as the length of lines becomes shorter. Thus, at 20 pitch the equivalent pressure-angle change is ± 6 minutes, at 100 pitch ± 29 minutes, and at 160 pitch it becomes ± 43 minutes. When the influence of lead error, as it affects profile accuracy, is superimposed on the pressure angle tolerance of the hob, it becomes obvious that the profile of the work produced by fine-pitch hobs cannot approach the accuracy of coarse-pitch hobs.

Measurement

There are several factors which should be considered when comparing relative accuracy of coarse and fine-pitch tools. One is the ability to verify a measurement. Some time ago, at a symposium on measuring instruments, held by the American Gear Manufacturers Association, it was brought out that to expect verification of gear profile error measurements closer than 0·0001 in. was unreasonable. No two instruments made by different manufacturers could be expected to verify profile errors to closer measurements. This means that a manufacturer of a 20 diametral pitch must have at least 0·0001 in. as a reading error. The allowance left for wheel wear, deflection, and error in a truing device is another 0·0001 in.

At the same symposium it was brought out that gears and cutters finer than approximately 80 pitch could not be reliably checked for profile with indicating devices, because the stylus becomes too flexible. At 100 pitch, for instance, the point of the tracing stylus of an involute checker could not be more than 0·004 in. thick. The indicating pressure on such a stylus would cause it to bend more than the allowable tolerance. At 160 pitch, where the point width of the stylus could be not more than 0·002 in., it would be impossible to make a reliable check. For this reason, a profile check of fine-pitch hobs and gears is made by means of optical comparators. No manufacturer of optical comparators, however, will guarantee a measurement of tooth profile closer than ± 0·0002.

It is obvious, then, that the measurement of a profile within a tolerance of ± 0·0002 in. on a 160-pitch hob whose whole depth is only 0·0158 in. is at best beyond the ability of the instrument. At 100 pitch, with a whole depth of 0·024 in., more accurate measurements can be made.

Gear Shapers

Many fine-pitch gears are cut on gear shapers. There is an excellent machine on the market for shaping gears of 3-in. diameter and smaller. The cutter used on this machine is approximately 1½ in. in diameter. Cutters for this machine can be obtained only from the manufacturer of the machine. These cutters are ground on a special machine by a double-conical grinding wheel, approximately 20 inches in diameter.

The wheel is dressed to the correct pressure angle and represents a single tooth of a generating rack. The cutter rolls past the grinding wheel and the involute curve is generated by duplicating the action of a gear meshing a rack. The centre of the wheel is set in the centre of the active face of the cutter, which for 100 pitch and finer is approximately 0·200 in. The curvature of the wheel leaves a slight hollow at the root and sides of the cutter teeth. This curvature, for all practical purposes, is of no consequence.

While cutters of 160 pitch and finer have been made on an experimental basis, production of appreciable quantities presents serious problems. If the fragile wheel is forced too rapidly into the cutter blank,

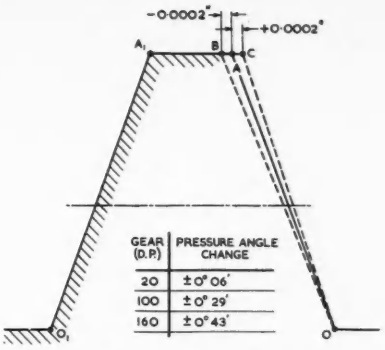


Fig. 3. **Relative pressure-angle change for hobs of 20, 100, and 160 D.P., based on a linear deviation of ±0·0002 in.**

accuracy is lost. Because of this limitation, production time becomes prohibitive. Furthermore, these same grinders are also used for grinding master gears and other types of cutters.

An expedient used by cutter manufacturers to overcome point-width difficulties is to omit every other tooth from the cutter. This gives a practical wheel point width. Cutters of this type are made for cutting a gear having an odd number of teeth. When cutting gears with an even number of teeth, sections with every other tooth removed are made with recurrent sections in which two teeth are removed.

During the cutting operation, the work is geared up to the cutter in the conventional manner, as if it had a full complement of teeth, but the work must rotate twice in order to pick up the spot where the tooth was left out of the cutter. The chief limitations with cutters of this type are: (1) They tend to accentuate the errors of the indexing mechanism when the work makes the second revolution; and (2) production is much slower.

The same general measurement limitations apply to gear-shaper cutters and hobs. A tooth-to-tooth error allowance of 0·0002 in. is permitted at 160 pitch, just as it is at 20 pitch. It should be realised that a pitch error, at 20 pitch, of 0·0002 in. is far less disturbing, motionwise, than a similar error at 100 or 160 pitch.

The general tolerance on circular pitch of a 20-pitch gear shaper cutter is ± 0·0002 in. The same tolerance is required for pitch error at any pitch. This, as mentioned before, is because the cutter manufacturer cannot hold a closer tolerance. Some cutter manufacturers make special cutters with precision tolerances, in which the pitch and profile error is held somewhat closer than that of a commercial cutter. These cutters are the result of painstaking workmanship and cost considerably more than commercial cutters. Precision cutters cannot be obtained in the ultrafine pitch because limited wheel point-width and deflection present serious manufacturing problems.

The arc span of a 20-pitch cutter is 0·1571 in., while that of a 160-pitch cutter is 0·019648 in., or only one-eighth as much. If the first tooth of the 160-pitch cutter is farther from, or nearer to the second tooth by 0·0002 in. than 0·019648 in., it is acceptable. The same applies for tooth No. 9. Thus, through a span of 0·1572 in. (eight pitch increments), the 160-pitch gear can be off twice as much over a similar arc-span as the 20-pitch gear or cutter. It is understood that the ± 0·0002 in. error is non-cumulative.

If the 20-pitch gear or cutter is rotated through circular increments equal to the circular pitch of the 160-pitch gear or cutter, it will be found that, all other things being equal, it will transmit angular motion approximately eight times more accurately than a 160-pitch gear of the same diameter.

One of the strong arguments in favour of fine-pitch gears as against coarse-pitch has been the longer arc of action and the beneficial integrating effect obtained therefrom. This argument is valid to a certain point. When tooling and measuring difficulties outweigh the advantages gained by increased contact, the point of diminished returns has been reached.

The difficulties of producing gear-shaper cutters of 160 pitch on an economical basis have been discussed. The same arguments hold true for circular master gears. Shaving tools, so necessary to achieve accuracy in precision gears, are not generally obtainable in 160 pitch. While one or two experimental shaving tools have been made in this pitch range, it is doubtful whether any manufacturer would accept an order for such a tool with a full complement of teeth. Circular master gears, with every other tooth removed, would also present a checking problem. The checking operation would have to be done twice for the master to explore every tooth of the gear. Also, a tooth-to-tooth error could not be detected with a master having every other tooth removed.

This states the case of tooling difficulties when using ultrafine pitches. With regard to the question of the practical limit, the answer depends to some extent on the type of gears. For instance, the American standard for fine-pitch straight bevel gears points out :—" In practice, most of the fine-pitch straight bevel gears lie between 20 diametral pitch and 64 diametral pitch." Straight bevel gears finer than 64 pitch have been and are being made, in spite of the problems they present in tooling and measuring. However, careful study might disclose that a coarser, more practical pitch could be used.

There is general agreement among tool manufacturers and gear engineers that the point of diminishing returns hovers around 100 diametral pitch.

Examples

Examination of two cases taken from recent production shows how pitch substitution will, for all practical purposes, satisfy the design conditions.

Specifications for Case No. 1, involving substitution of a 100-diametral pitch gear set for one of 160 pitch, are listed in Table I.

Table I.—Substitution of Gear Sets with 9 to 1 Ratios.

Part	Diametral Pitch Combination			
	160		100	
	Gear	Pinion	Gear	Pinion
No. of teeth	99	11	63	7
Standard P.D. [in.]	0·61875	0·06875	0·630	0·070
Operating P.D. [in.]	0·614	0·0735	0·618	0·082
Outside Diameter [in.]	0·626	0·086	0·641	0·0983
Pressure Angle [deg.]	20		20	
Centre Distance [in.]	0·350		0·3437	
Mean Contact Ratio	1·362		1·389	

The difference in contact ratio between the 100 and 160-diametral pitch combination is negligible. The difference in centre distance is 0·0063 in., the 160-pitch combination having slightly closer centres. It would have been possible to meet the exact centre distance requirements of 0·3437 in. specified for the 160-diametral pitch set of gears, with the 100-pitch gears by reducing the gear and using standard proportions (not enlarged) on the pinion. This would have resulted in a slightly lower contact ratio and a weaker pinion.

Case No. 2, shown in Table II, illustrates another example of how a 150-pitch gear set was replaced by 100-pitch, with perfectly satisfactory result. In fact, the 100-pitch gears ran more smoothly and lasted considerably longer than the 150-pitch set.

In this case, it was possible to meet the exact centre distance requirements. The difference in contact ratio,

Table II.—Substitution of Gear Sets with 10 to 1 Ratios.

Part	Diametral Pitch Combination			
	150		100	
	Gear	Pinion	Gear	Pinion
No. of teeth	120	12	80	8
Standard P.D. [in.]	0·800	0·080	0·800	0·080
Operating P D. [in.]	0·796	0·084	0·7894	0·0906
Outside Diameter [in.]	0·8093	0·0974	0·809	0·1087
Pressure Angle [deg.]	20		20	
Centre Distance [in.]	0·440		0·440	
Mean Contact Ratio	1·528		1·305	

at first glance, would seem appreciable. Actually, it is only 17%, which is not an important difference, especially when it is considered that a reduction in outside diameter in the finer pitches affects their contact ratio much more than an equivalent reduction for coarser pitches.

There has been too much emphasis placed on the importance of having as large a contact ratio as possible. The beneficial integrating effect of a high contact ratio is cited as an important consideration. In the first place, there is less need to integrate out the errors, if they are reduced during production, as is the case when coarser pitches are used. Secondly, a contact ratio in fine-pitch spur gears beyond that which insures continuous action (somewhere between 25 and 30% more than one base pitch) is useless. It is conducive to premature wear in highly stressed high-speed gears. Many cases of increased gear life are on record where nothing was done to the gear sets other than to reduce their contact ratios. In motion drives where optimum angular transmission is desirable, the requirements are different. In such slow moving drives, a high contact ratio is desirable. Drives of this kind must be as accurate as possible in all respects, and the inherent accuracy limitations of the ultrafine pitches will not satisfy the operating requirements.

The two cases cited as examples, where 100-pitch gears were substituted for finer pitches with satisfactory results, can be multiplied many times. It is not claimed, however, that all designs can be made to respond to the same treatment. There are no doubt many designs in which ultrafine pitches cannot be avoided.

CHARACTERISTICS AND CONTROL OF ELECTROSTATIC GENERATORS

(*Concluded from page* 153)

are equal to those of the point electrode) relative to the latter. Although this effect is unfavourable, as it eventually increases the slope of the resultant characteristic instead of reducing it, it can be corrected by lining the interior of the metal box with an insulating material.

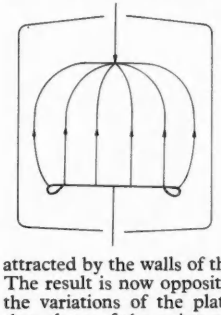


Fig. 6. **Lines of force of discharge inside a hollow insulator.**

In consequence, the lines of force are considerably deflected, as shown in Fig. 6, and instead of being attracted by the walls of the box, are now repulsed by it. The result is now opposite to that previously indicated, the variations of the plate potential becoming greater than those of the point, and causing a reduction of the slope of the resultant characteristic, which now may even disappear.

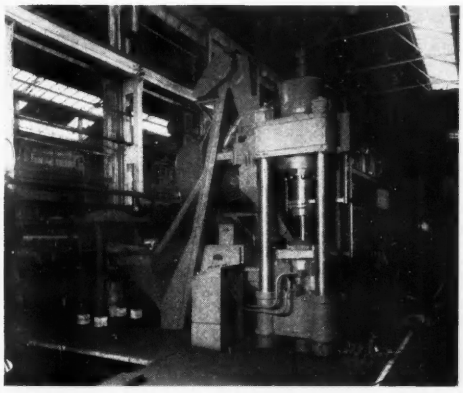
New Materials, Processes and Equipment

HYDRAULIC BRIQUETTING PRESS

There is a latent demand in industry for equipment designed to assist in the conservation of ferrous and non-ferrous materials of a type not readily processed by conventional baling equipment. To meet this requirement, Fielding & Platt Ltd., of Gloucester, have produced a 400-ton hydraulic briquetting press, with many outstanding design features and with wide possibilities for the recovery of cast iron.

The machine is fully automatic in operation, and is capable of converting small cast iron machinings into high-density briquettes at a constant and rapid production rate. The process needs no bonding or sintering, and the briquettes when made can be conveniently handled and conveyed directly from the press to the cupola or furnace for re-melting.

The press is of the vertical four-column type, having fabricated tables with a mould assembly mounted on the bottom table ; it is self-contained and complete with its own hydraulic pumping unit, using oil as the pressure medium, supplied from two high-speed radial pumps driven by one 80-hp and one 50-hp motor. Control is by electrical pushbuttons through d.c. solenoid-operated valves of the balanced type for operating with oil, complete control equipment being arranged for automatic operation.



In operation, swarf is loaded into a bunker, whence it pours on to a vibrating screen. This screen will reject large pieces of metal or other unsuitable material, which will then be carried away down a small reject chute fitted at right angles to the direction of flow. The screened material then passes into a reservoir at the foot of an elevator, from which it is carried to a small hopper at the top of the machine by flights attached to the elevator chain. A vibrator attached to this hopper ensures a continuous supply of swarf into a dispenser, which is an automatic device for measuring by weight the correct amount of swarf required to make one briquette. After filling, it is tipped by air cylinders, in order to discharge its load down a chute and into the mould, ready for briquetting. As soon as the swarf is discharged, the dispenser is immediately returned to its original position.

The main ram mandrel now enters the mould or container and presses a briquette. Pressure is then locked in the main cylinder, while the mould is lifted by four small lifting rams and the briquette is stripped from the mould. The main ram is then returned to the UP or FILLING position, thus completely releasing the briquette, which is then ejected from the press by the plunger of a horizontal air cylinder. The finished briquette is then pushed down a small chute to a suitable receptacle or conveyor, The mould is then returned to the FILLING position, when the dispenser will supply a new charge of swarf as before and the operation will be repeated.

The machine has an hourly output of about 300 to 340 briquettes of 4 to 6 lb each, and the bunker has a capacity of approximately 1 ton, or sufficient for about 1 hour of continuous operation.

HOT-SPRAY UNIT

With the introduction of their new ECCO H3B hot-spray unit, the Atlas Diesel Company Ltd., of Wembley, claim to be the first manufacturers to guarantee continuous performance with two guns used independently.

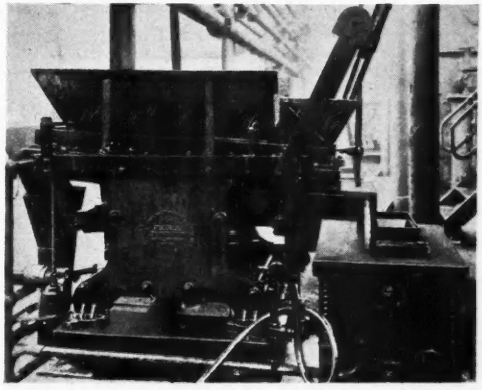
In this new unit, which is a modification of the old unit, an adaptor has been fitted to the side of the distributor block. This adaptor successfully allows two spray guns to be fed from the unit, ensuring compensation of the fluid pressure in both lines. The new unit is fitted with a 3½-kW heater instead of the old 2¼-kW heater and still maintains the temperature and pressure with two guns that previously it did with one. An additional feature of this modification is that existing users of the H3B can have their plants modified for two-gun operation by the purchase of a higher-powered immersion heater and the adaptor, apart from the additional spray guns and hoses.

The fluid pump now incorporates a gland of a different type and design, thereby eliminating the possibility of the gland breaking down, as sometimes occurred in the past when the plant was not properly maintained or was run at too high a pressure.

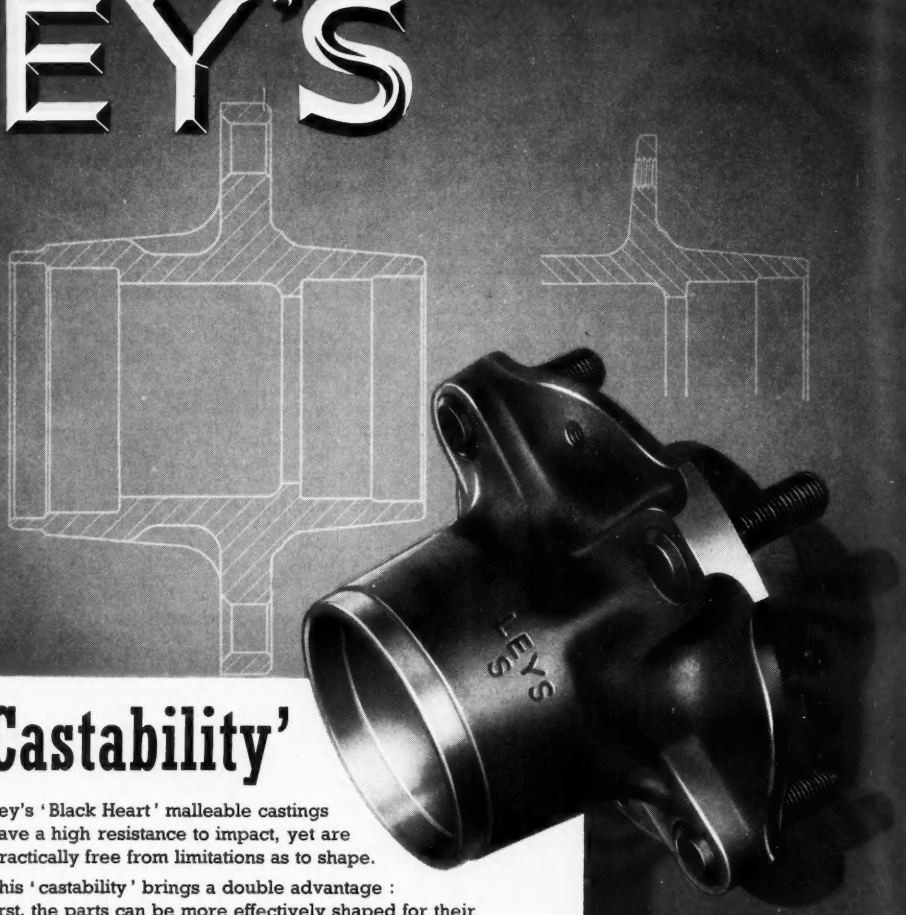
FILTER FOR COKE-OVEN TAR

The presence in coal tar of suspended particles of solids causes considerable difficulties, particularly in the case of coke ovens. These solids settle out in tanks and separators, blanketing heating coils, and thus prevent the proper heating of the tar necessary to ensure effective separation of the liquor.

Many attempts have been made to separate these solids from the tar, but a filtration problem of this type is not easy. Considerable success, however, seems to be attending a new design of filter, produced by Messrs. Russell Constructions Ltd., of London,



LEY'S



'Castability'

Ley's 'Black Heart' malleable castings have a high resistance to impact, yet are practically free from limitations as to shape.

This 'castability' brings a double advantage : first, the parts can be more effectively shaped for their ultimate purpose ; second, this freedom from limitations generally means that less metal has to be removed.

Coupled with the easy machinability of Ley's 'Black Heart', these factors are a great manufacturing asset, moreover the finished part is better suited to its duties.

The illustrations show, actual size, the front hub of a popular car, made from Ley's 'Black Heart', completely machined.

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STRENGTH & RIGIDITY

We offer designers the full collaboration of our engineers.

LEY'S

W.C.2, and adapted for the special purpose of filtering coke-oven tar at the Beckton Gasworks of the North Thames Gas Board.

The filter consists of a stainless steel screening cloth, which is vibrated at a high frequency but very small amplitude. Tar to be filtered pours on to this screen cloth, which is held in an essentially horizontal position. The solid material is retained on the cloth and is continuously brushed off into a receiving vessel at the end of the cloth. The filtered material passes into the tar-collecting system. With a normal coke-oven tar, the 120-mesh cloth used removes approximately 1% of sludge, which contains approximately 20% of dry solid material. This sludge is retained, and can be effectively removed from the system.

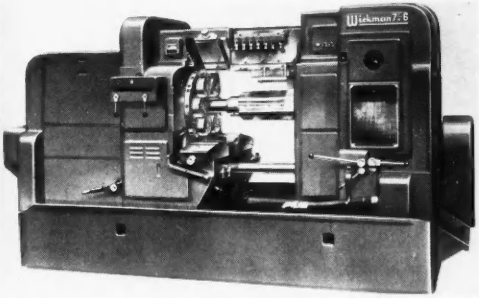
The most interesting operational characteristics of this filter are the following :—There appear to be no signs whatever of the screen cloth " binding " ; the tar feed can be interrupted for long periods and, provided a hot tar feed is restored, the plant restarts work satisfactorily ; and intermittent feeds of hot liquor do not interfere with the passage of the tar through the screen.

The illustrations shows a view of the unit at Beckton Gasworks, where, up to the present, approximately 500,000 gallons of tar have been satisfactorily filtered through the unit at the rate of 1,000 gallons per hour.

MULTI-SPINDLE AUTOMATIC CHUCKING MACHINES

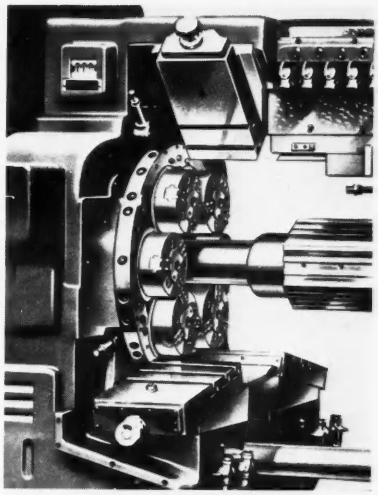
Two new large chucking machines are announced by Wickman Limited, of Coventry, as a further extension to their range of multi-spindle automatics, and offer new opportunities for fast, accurate, and economical machining of castings, forgings, billets, and pressings.

Developed from their 4- and 6-spindle series of bar automatics, these new machines provide a chuck capacity of 9 in. in the 4-spindle version and 7¼ in. in the 6-spindle arrangement. Many of the features which have long characterised the Wickman range are incorporated, notable among these being the patented lever adjusting mechanisms for alteration of tool-feed strokes without changing cams. The new machines are extremely heavy and rigid, total weight without tooling being approximately 12 tons.



Power is supplied by a 30-hp, 960-rpm, foot-mounted motor on a hinged platform, the drive being transmitted by heavy, matched V-belts. Spindle speeds range from 29 to 473 rpm on the 4-spindle machine, and 51 to 675 rpm on the 6-spindle machine. Power, and feed and speed ranges have been chosen to cover the widest field of use and to enable the fullest possible exploitation of carbide tooling.

The spindles are heat-treated steel forgings, designed with large integral flanges for mounting chucks, and run in extra-precision taper and parallel roller bearings. A large multi-plate clutch and brake, operated by an individual fork, are fitted to each spindle. Light-action levers electrically control the air cylinders which operate the spindle clutch, brake, and chuck, and interlocks are fitted to prevent incorrect sequence. Under



normal operating conditions (with no tooling in the loading station), the spindle is automatically stopped after completion of indexing, ready for unchucking the completed work. When accelerated end-working tooling is used in the loading station, adjustable timing cams stop the spindle automatically only when tools are clear of the work. Operator safety is ensured by two-hand pushbutton controls linked with a warning light system, and by a mechanism which trips the feed clutch automatically before indexing, if the buttons have not been depressed.

Chucks are supplied with interchangeable hardened base jaws and wedges with optional wedge angles, to provide the greatest gripping power or movement. Loading is performed right-handed at station 6 on the 6-spindle machine and at station 4 on the 4-spindle machine. Indexing is anti-clockwise, so that the heavier roughing operations are carried out on the lower stations. Double indexing can be arranged on the 6-spindle machine, loading then being carried out at stations 5 and 6, with individual controls to each station. Cross-slides are fitted as standard in stations 1 and 2 and, if required, in stations 4 and 5 on the 6-spindle machine and stations 3 and 4 on the 4-spindle machine. All cross-slides have micrometer adjustment and are provided with a master stop, engaging stop screws in the spindle drum.

The main tool block is provided with a dead stop and step-by-step endwise adjustment, so that the position most favourable to the set-up can be used, dependent upon length and swing of work, stroke, and tooling. Independent upper end-working slides are also available in stations 4 and 5 on the 6-spindle machine and in stations 3 and 4 on the 4-spindle machine. Standard toolholders are available for a wide range of tools, which in many cases are interchangeable between stations and machines of both bar and chucking type. Attachments for high-speed drilling, independent reaming, plain threading with self-opening revolving diehead, or full threading with solid taps and dies are available.

A general view, and a close-up of the tooling area, of the 6-spindle machine are illustrated.

STEAM ATMOSPHERE FURNACE

In view of the apparently growing demand for a standard furnace for blueing such components as drills, electrical parts, and other articles requiring a rust-resisting finish, Birlec Limited, of Birmingham, have

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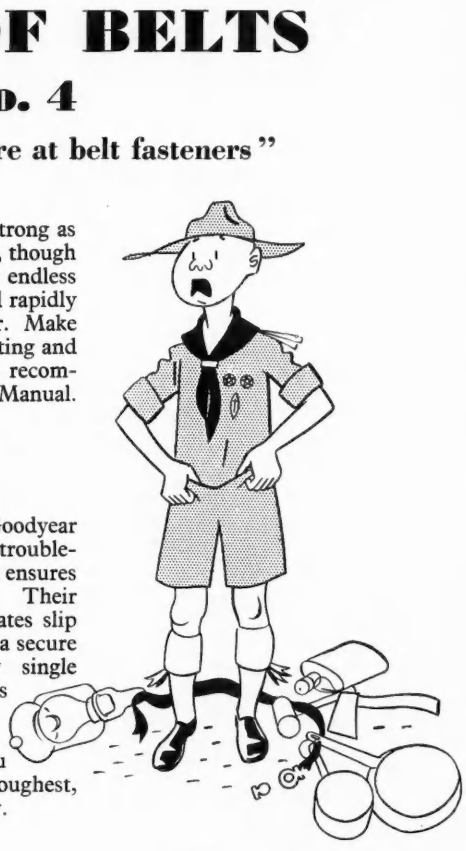

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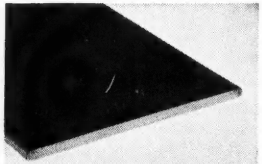
HOW TO GET LONGER LIFE FROM INDUSTRIAL RUBBER PRODUCTS

Compiled by Goodyear's own technicians the Goodyear Maintenance Manual is the best practical guide to getting longer and more efficient life from industrial rubber equipment. Please write to Dept. K.4, Goodyear Tyre & Rubber Co. (G.B.) Ltd., Wolverhampton, for your free copy of this valuable book.



GOODYEAR THOR FOLDED EDGE BELT

This belting is used in mills and factories throughout the world; appreciated for long dependable service. It combines resistance to shock loads with exceptional ability to hold fasteners. Plies of closely woven silver duck and an additional skim coat between plies enable it to perform outstandingly on the most exacting drives.

GOODYEAR

INDUSTRIAL RUBBER PRODUCTS

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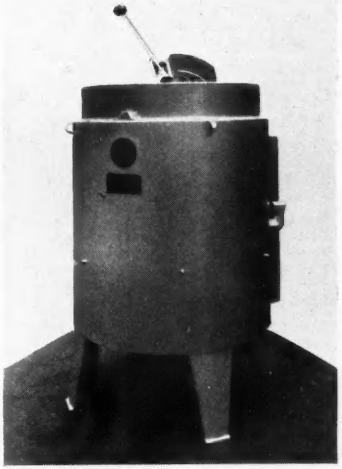
developed a new range of vertical furnaces especially designed for use with a steam atmosphere and capable of operation at temperatures up to 700° C.

The furnace is of the vertical, cylindrical type and is built on orthodox lines with a brick-lined steel shell. An interior metal container covers the main brick-work, so that the furnace bricks will not absorb the steam. A hand-operated cover or lid is supplied and the lifting equipment is designed so that no elaborate clamping methods are needed to ensure a gas-tight seal. Electrical insulators are mounted on the inner face of the metal container to carry the heating elements, an arrangement which ensures that heat is imparted directly to the charge by means of the air circulation system. A centrifugal fan and suitable baffles are provided to ensure absolute temperature uniformity throughout the charge space. Steam is admitted to the furnace chamber near the fan and the outlet is provided at the top of the chamber with drain valves at suitable points. The steam, which requires a pressure of only a few pounds, can be taken from the normal factory supply or, where this is not available, a separate small and relatively cheap boiler can be provided. All heating-element lead-outs and other possible sources of leakage, such as the fan shaft, are sealed and fitted with glands to prevent the escape of steam.

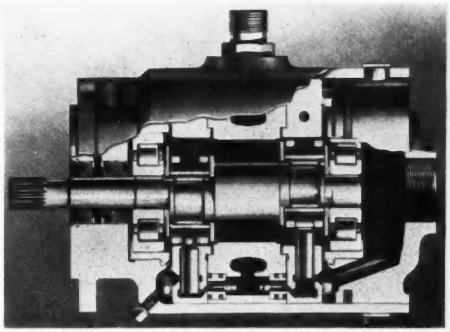


The new standard furnace can be employed for heat-treatment applications other than steam atmosphere work where temperatures up to 700° C are required, such as the tempering of carbon steel tools and components, the annealing of copper and brass, and the solution treatment of aluminium. This feature makes the furnace particularly attractive in small plants where, even though a furnace may be installed primarily for steam atmosphere work, it can be switched over, if required, to other low-temperature operations.

HYDRAULIC PUMP FOR AIRCRAFT

A new engine-driven hydraulic pump for aircraft is announced by the Aircraft Division of the Lockheed Hydraulic Brake Co. Ltd., of Leamington Spa.

The new pump, known as the Mark 8, has twice the output of the Mark 7, which was previously the largest-capacity pump made by Lockheed. Structurally, the new unit has many of the features of the Mark 7 and might be described as a " double-banked " Mark 7. The latter is a 7-cylinder radial plunger pump, actuated by an eccentric shaft integral with the driving shaft, whereas the Mark 8 has 14 cylinders arranged in two radial banks, and is actuated by a balanced two-throw eccentric shaft. Because of the multiplicity of cylinders, the hydraulic system is completely free from the pressure



pulses which are unavoidable when pumps with comparatively few cylinders are employed.

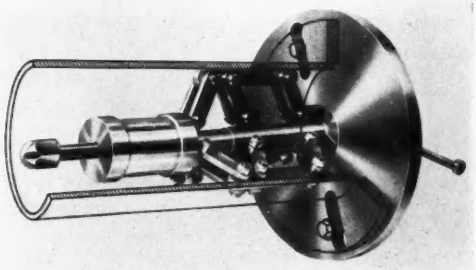
Like the Mark 7, the new unit is a straightforward pumping unit, with no offloading devices or other features which might impair its efficiency. Furthermore, it does not generate excessive heat, even under maximum load. The inlet porting is automatic; a groove is cut in each cylinder in such a position that it is partly uncovered shortly before the plunger reaches the bottom of its stroke. On the compression stroke, the plunger covers the inlet port, and trapped fluid is forced through a passage leading from the top of the cylinders, past a delivery valve into an annular passage in the high-pressure end cover leading to the outlet connection.

Non-inflammable and other water-based liquids can be used in systems associated with the pump, and the shaft seals are resistant to the new synthetic turbine oils now becoming popular.

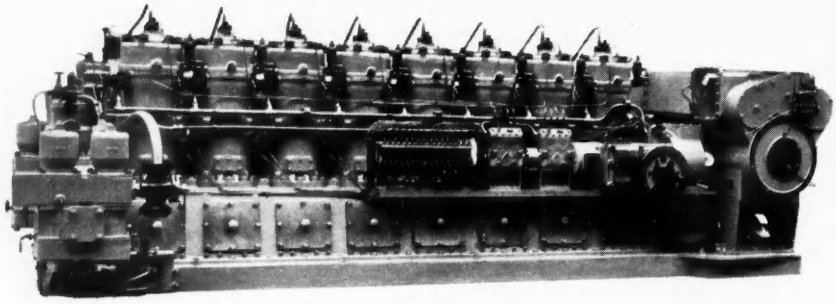
The rated maximum working pressure of the Mark 8 pump is 3000 psi, rated minimum delivery at 3000 psi and 3300 rpm being 5·12 gpm, with an approximate horse-power of 12·9. Rated maximum cruising speed is 3300 rpm, and overspeed at 3000 psi is 4000 rpm. This performance does not represent the pump's final development; when the need arises, it can be raised appreciably.

PIPE-FLANGING JIG

A new tool has been designed by Donald Ross & Partners Limited, of London, N.W.1, to meet the problem of ensuring accurate squareness of " slip-on " flanges to the bore of pipes when welded. It is also used for internally lining up " welding-neck " type flanges for butt welding to pipes.



When using the Twinner Pipe-Flanging Jig, as it is called, the flange is pushed over the pipe. The jig is inserted into the pipe and, by turning the tommy bar, the links are expanded to press against the inside wall of the pipe. As the links are always parallel in any position, this ensures that the clamping plate is square to the pipe. The flange is secured by two bolts to the clamping plate and tack-welded on the outside. The jig is now removed,

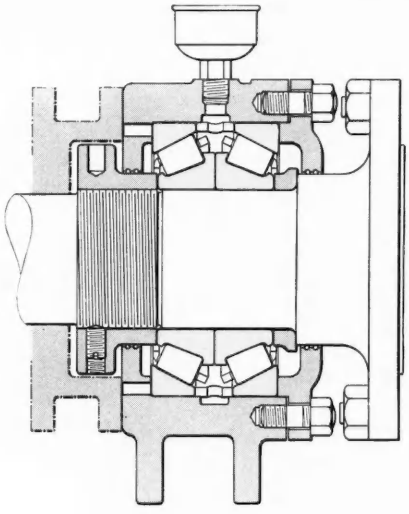


THRUST

Timken tapered-roller bearings, with their capacity for carrying both thrust and journal loads, can be made with steeper angles than normal for applications in which thrust loads predominate.

The illustration at the top shows a Widdop EMB-8 eight-cylinder 2-stroke direct-reversing marine propulsion engine. Propelled by one of these engines, a coaster made its delivery trip to British Guiana (4,740 miles).

The line drawing shows the arrangement of the Timken double-thrust bearing in the thrust block, of which an exterior view is shown below.



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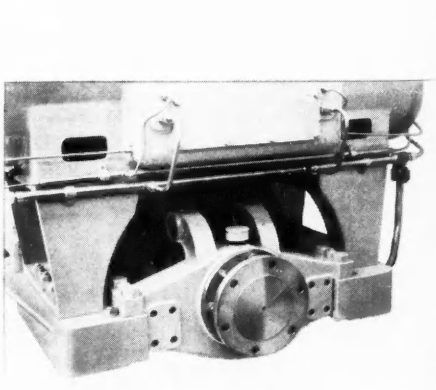


and the internal weld completely made, followed by the external weld. No skill is required in using the device.

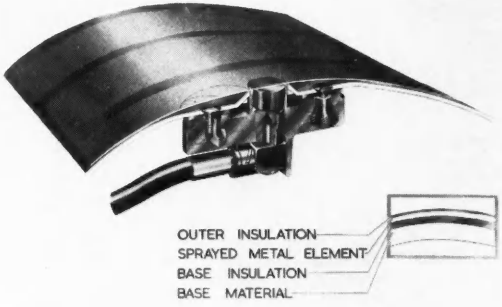
When used for welding-neck flanges, the flanges are pushed over the links of the jig, which is inserted into the pipe and expanded. Lining up of the two components is automatic and a gap can be left to suit welding requirements. The complete weld can be made with the jig in position.

These pipe-flanging jigs are of all-steel construction and are manufactured in five sizes, to suit pipes ranging from 2 to 18 in. bore.

AIRCRAFT DE-ICING SYSTEM

A new de-icing system, developed to provide protection for all types of aircraft and for aero-engine air intakes which are difficult to protect by any other means, is announced by D. Napier & Son Limited, of Acton, London, W.3.

The basic requirements of a heater mat for ice-protection applications show that it is advantageous to fabricate the heater by a spraying process directly on to the surface to be protected, particularly when compound curvatures are considered, bearing in mind the normal tolerances possible in sheet-metal work and the difficulties of applying a prefabricated mat without entrapping air at the attachment face. Such trapped air is liable to cause blistering and overheating when heat is generated by the elements; a sprayed application of the base insulation, however, ensures intimate contact with the surface.



In this connection, the Napier Surface Heater De-Icing System is applied with a spray gun. In the construction of the heater mat, as shown in the illustration, the base insulation consists of a layer of thermosetting resin applied by a flame spray gun. The electrical conductor is a metal, similarly applied, to the resistance and pattern called for by the particular heat distribution required, and is provided with suitable terminals for connection to the electrical system. The outer insulation, of similar material to the base layer, is sprayed on and is finally finished as a highly polished surface. The heater mat may then be coloured to conform with the required specification, without affecting its characteristics in any way.

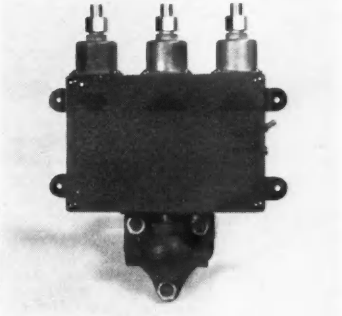
The advantages of the system are that it is light and that it provides efficient de-icing over large areas of the aircraft's surface. It can also be used on parts of the aircraft which are too small to be fitted with other de-icing systems. It imposes only moderate loads on aircraft generators, it permits ready access to the parts of the aircraft which it covers, its maintenance cost is very low, and it gives long service. Furthermore, should repairs be required, these can very easily be effected with a stencil and a spray gun.

The system has already been airborne in flight tests for 1500 hours, and has been subjected to 100 take-offs and landings at Khartoum to tests its resistance to sand abrasion. Additional tests of 220 hours duration have proved that it can withstand the erosion effect of rain at high speeds, and it is established that the equipment imposes no stress limitations on the wings of an aircraft to which it is fitted.

PROTECTION UNIT FOR DIESEL-POWERED AIR COMPRESSORS

To meet the requirements of diesel-driven air compressors where no electric supply is available, Teddington Industrial Equipment Limited, of Sunbury-on-Thames, Middlesex, have developed a new control unit to provide fully automatic protection against failure of diesel-engine lubricating-oil pressure, compressor lubricating-oil pressure, and excessive intercooler pressure.

This instrument is contained in a neat cast housing, with three pressure-sensitive elements mounted externally; in the event of the lubricating-oil pressure of either the diesel engine or the compressor falling below a pre-set value, the control operates a small integral air valve, which allows the air pressure from the compressor receiver to be applied to the pneumatic piston attached to the diesel fuel pump. The valve is also operated by an increase in the intercooler pressure beyond a pre-set level. All three elements are independently adjustable for all normal requirements. A manual reset lever is fitted, and this must be held in the operating position during starting, until normal operating pressures are established.



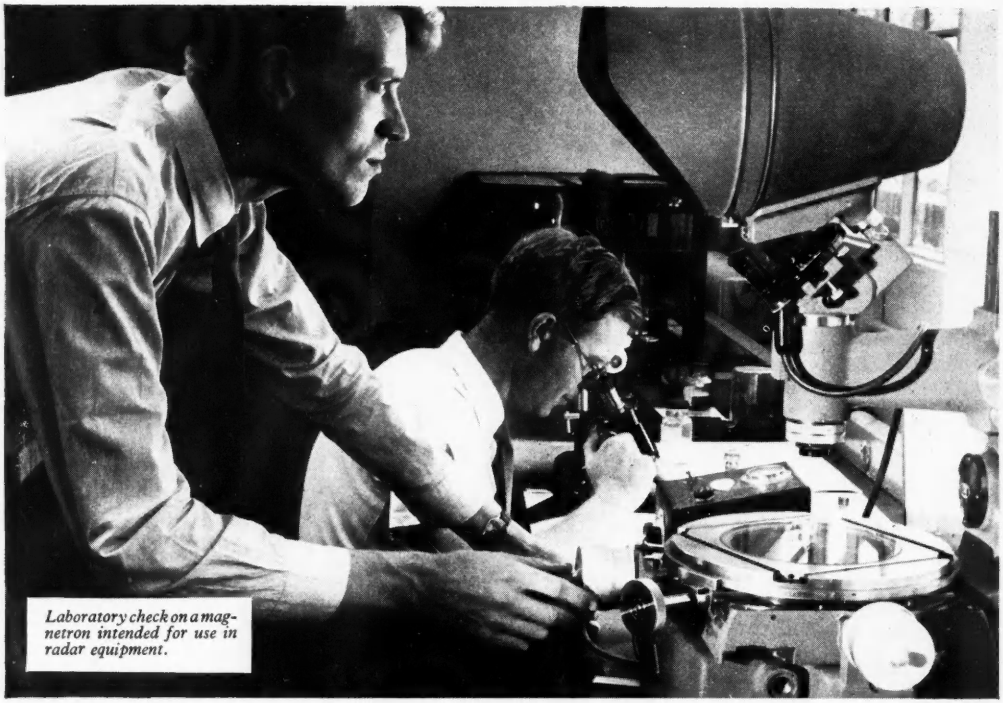
The unit is of simple, inexpensive construction and is designed for use under the rather arduous conditions associated with mobile road-drilling machinery and other outdoor applications.

LIGHTWEIGHT PNEUMATIC SNAP-JACK

The development of three types of lightweight, high-thrust, pneumatic snap-jack is announced by the Hymatic Engineering Co. Ltd., of Redditch, Worcs. Utilising air stored at 3000 psi and needing no external pressure system, these snap-jacks are designed for such aircraft applications as canopy or hatch ejection, emergency-cock operation, safe jettison of wing-tip and drop-tanks, and the emergency operation of lock mechanisms.

Air under pressure is stored in the hollow spindle of the jack and retained by a replaceable metal diaphragm situated in the piston. As soon as a load of 6-8 lb is exerted on the operating pin, the diaphragm is fractured, the air passes into the cylinder and, acting on the full piston area, extends the jack very rapidly—about $\frac{1}{4}$ sec for a 3-in. stroke. Accidental operation is prevented by the provision of a safety pin, which is withdrawn after installation and charging, or just before the take-off.

Among the many advantages offered by these self-contained emergency actuators is the appreciable reduction in weight. They are, for example, from 4 to 10



Laboratory check on a magnetron intended for use in radar equipment.

PROGRESS IN ELECTRONICS

THE possibility of using radio to detect and locate unseen objects has intrigued scientists since the turn of the century, but it was not until the advent of the multi-cavity magnetron during the late war that the history of modern radar began.

Radar targets are located by a beam of radio waves which upon striking an object are reflected to the sender. The direction of the beam when it is reflected, and the time taken by the waves on their outward and return journeys, indicate the exact position of the target.

For the system to be sensitive and accurate, the range of the transmitted beam must be long and its width narrow. This requires a powerful source of radio waves of very short wave-length but, unfortunately, such "microwaves" cannot be provided by an ordinary electronic valve. Faced with these difficulties the early radar pioneers developed the multi-cavity magnetron — a special valve which proved to be more powerful by a factor of hundreds than any other microwave generator then available.

Today, magnetrons are playing an essential part in radar navigation. Ships and harbours are no longer hidden by fog and mountain peaks cease to be obscured by cloud. The cathode ray tubes of air and sea navigators present pictures of the way ahead even when visibility is zero.

Radar science is still undergoing ingenious and complex development. In the field of meteorology it is used for detecting and "tracking" clouds, as well as obtaining upper air measurements of wind velocity. A different role is also being played by the magnetron in accelerating electrons for the production of high-energy X-rays. In these and other microwave applications Mullard are contributing to further progress with the large-scale manufacture of high quality magnetrons and similar electronic devices.

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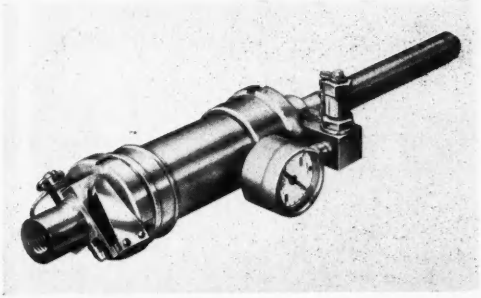


times lighter than a spring providing the same stored energy. Moreover, there are no fire risks and no transport or storage problems, as they may be charged with air after installation. If desired, a pressure gauge may be fitted, as shown in the illustration, to indicate if the jack is ready for service. The metal diagpragm naturally does not deteriorate with age nor does it permit loss of air through micro-porosity, so that the storage pressure is retained for long periods without attention.

The three types so far available, all operating within a temperature range of —40° C to +70° C, are designated the Hymatic RES6, RES1, and RES2, respectively. The RES6, utilising a stored energy of 2200 ft-lb, develops an initial and a final thrust of 9000 lb and 2280 lb respectively for a 6-in. stroke; the RES1, with 600 ft-lb, develops 4750 and 1250 lb for a 3-in stroke; and the RES2, with 238 ft-lb, 3500 and 1000 lb for a stroke of 1·6 in. The total weights of the three types are 3·5, 2·6, and 0·9 lb respectively.

FLAME-FAILURE SAFETY EQUIPMENT

The latest series in the range of furnace safety systems manufactured by Elcontrol Ltd., of London, W.1, is the Elcontrol FSM system, which provides immediate fuel cut-off in the event of flame failure of oil- and gas-burning equipment. It thus provides complete safety under running conditions and, in addition, it can be arranged to give equally complete safety on lighting up, by preventing the admission of fuel until the means of lighting are actually present and in the correct position.

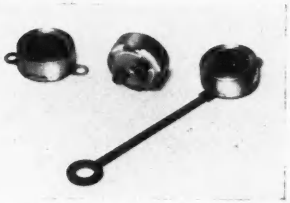
The principle employed in the new system is the detection of the fluctuating infra-red radiation, characteristic of every flame, both luminous and non-luminous. For this purpose, a viewing head (illustrated) is employed; this head embodies an infra-red-sensitive cell and lens system, which is sighted on to the flame through a tube of small diameter, located on the burner front or furnace wall, or axially along the burner tube, as convenient. The head is connected to the control unit, which incorporates the electronic circuit and operating relays and which responds only to modulated signals from the viewing head. Complete discrimination between the flame and hot refractory is thus provided, without recourse to a sensitivity control.

When the viewing head "sees" the flame, the control relay is energised, thus opening the magnetic valve or starting the burner motor. Absence of flame immediately causes the relay to be de-energised, giving instantaneous shut-down and operation of the appropriate alarm signal. The head, which is only $3\frac{3}{8}$ in. in length × $1\frac{5}{8}$ in. in diameter, is supplied complete with 6-ft leads in a flexible conduit, terminating in a junction box for connection to the control unit.

An instantaneous flame-failure protection device of this kind, with its freedom from risk of spurious operation due to incorrect installation, presence of dust, etc., should appeal to all concerned with safe lighting-up and running flame-failure protection of furnaces of all kinds.

MAKE-AND-BREAK THERMOSTAT

An extremely compact, quick make-and-break thermostat for close control of temperatures in electronic, appliance, and industrial apparatus applications is announced by Stevens Manufacturing Company, Inc., of Mansfield, Ohio.



Known as the "Stemco" Type A thermostat, the new unit uses a disc-type bi-metal thermal element, and it is stated that rapid response and close control are due to two main design advantages:—Firstly, the brass housing in which the bi-metal disc is carried is mounted against the controlled surface; as a result, the bi-metal element is in extremely close proximity to, and is heated by both conduction and radiation from, the controlled device. Secondly, since current is carried through a copper contact spring, which is insulated from the thermal element, the bi-metal element is electrically independent, ensuring fewer contact operations, and elimination of false cycling and life-shortening "judder."

The maximum operating temperature of these thermostats is 400° F; temperatures as low as — 76° F do not impair normal operation. A variety of terminal arrangements and styles is available. The illustration shows the standard (non-hermetically sealed) model.

ELECTRONIC COUNTER

The latest addition to the range of instruments and equipment manufactured by Davis, Wynn & Andrews Ltd., of Cheltenham, is their D.W.A. Electronic Counter, Model 2 DNR.

The unit, which is mains-operated, resettable, and capable of counting electrical pulses up to a rate of 5000 per second, consists of two Dekatron counter tubes, feeding a high-speed mechanical register, complete with the necessary power supplies and driver stages, all mounted in one neat cabinet, as shown in the illustration. Counter tubes indicate "units" and "tens," and the high-speed register indicates "hundreds," up to a maximum of one-hundred-million pulses.

A front panel switch starts and stops the count, and a spring-loaded switch resets the Dekatron tubes; the high-speed register is reset by means of knurled knobs. Indicator lights are provided for "mains on" and "count," and the protective fuses provided are accessible from the front panel. The input socket accepts

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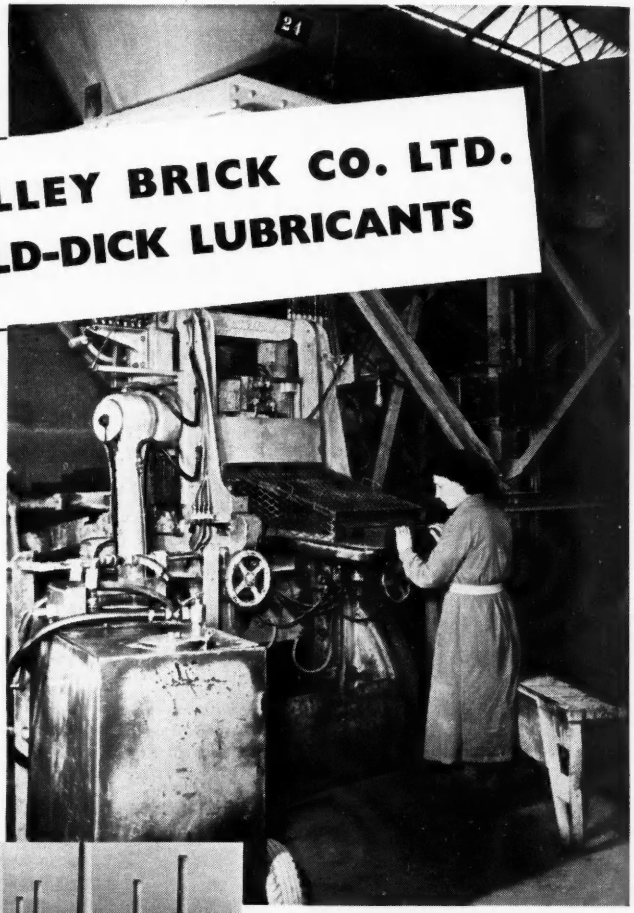

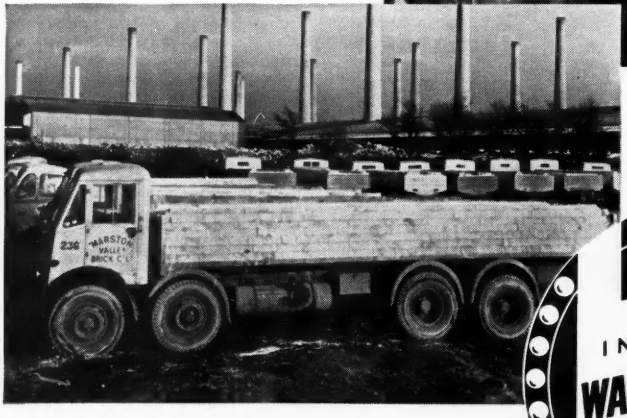

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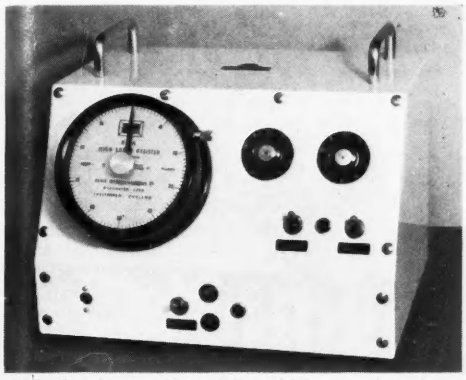


standard ¼-in. coaxial cable, which may be of any reasonable length. Two carrying handles are provided on the top of the cabinet, which measures approximately 12 in. × 9 in. × 9 in. high.

Pulse input is 10 V peak, positive or negative, though this can be varied within fairly wide limits, to suit individual requirements. Most types of " pick-up," to suit this equipment, can be supplied, if required.

Among other applications for the new counter is that of accurate speed counting of turbines, in conjunction with a D.W.A. crystal-controlled timing unit.

VIBRATING CONDENSER AMPLIFIER

A new vibrating condenser d.c. amplifier, for the measurement of small currents and voltages derived from a high impedance source, was featured by Electronic Instruments Ltd., of Richmond, at the Physical Society's Exhibition this month.

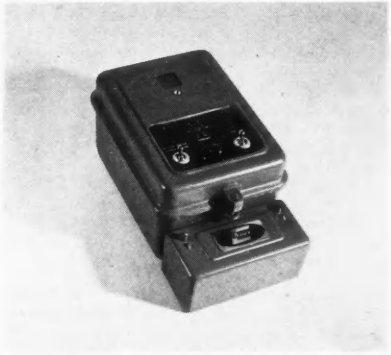
The heart of the amplifier is the " Vibron " condenser unit, which is provided with a standard octal base, and can be handled as simply as a conventional valve, which, outwardly, it closely resembles. The incoming d.c. signal is converted by the " Vibron " unit to a.c. and, after amplification, is re-converted to d.c. by means of a phase-sensitive rectifier.

The " Vibron " amplifier was exhibited in three different forms, i.e., as a general purpose laboratory instrument, as an industrial pH meter, and as a nucleonic weight gauge. The laboratory amplifier has input ranges of 10 mV, 100 mV and 1 V, and an output of 1 mA on all ranges. The input impedance is 10^{12} to 10^{16} ohms, according to the particular application. The zero stability is better than ± 100 microvolts and an interesting feature of the design is that the whole amplifier comprises only five valves, in addition to the " Vibron " unit. The industrial pH meter, shown as a prototype, is claimed to be the first British pH meter operating on the vibrating condenser principle. The zero stability of such an instrument is better than ± 0·002 pH. The nucleonic weight gauge has been specially developed for use with a beta-ray scanning unit and is an example of how the " Vibron " principle can be applied in this field, to provide increased sensitivity of measurement combined with exceptional zero stability.

The illustration shows the new vibrating condenser d.c. amplifier with, inset, the " Vibron " unit.

AUTOMATIC LIGHT-CONTROL UNIT

Among other examples of electronic control apparatus, manufactured by Elesta Elektronische Steuerapparate, of Bad Ragaz, Switzerland, and which will be exhibited at the Swiss Industries Fair next month, is a range of control units, designed for the automatic switching of lights in daylight and darkness.



Controls of this type are useful for automatic control of street lights, advertising, railway, and other signs, illumination of shop-windows, etc. These controls are of robust construction and small dimensions, and are easily adjustable to the desired degree of sensitivity. Their most important feature is a new and patented combination of a high-vacuum photo-cell and cold-cathode gas tubes, ensuring high sensitivity and stability and an extremely high life expectancy.

BRITTLE FAILURE OF STEEL-PLATE STRUCTURES

(*Concluded from page* 137)

ships that every fracture investigated could be traced to a starting point at a definite geometrical discontinuity due to design or workmanship. While the data are not complete for non-ship structures, it would appear that the latter conclusion is equally valid here. The importance of workmanship cannot be over-emphasised. One ship is known to have broken in half as the result of a fracture initiating at so small a thing as a crater left by an arc strike. Equally small defects are known to have initiated non-ship failures.

Crack Paths: A word might be said here about the path of a brittle crack, once failure has been initiated. Unless a weld is exceptionally bad, there is no tendency for a crack to follow welded seams. In fact, in one case, that of a spherical welded pressure vessel, 38 ft in diameter, there were 650 ft of brittle tears, with 20 fragments resulting. Only a few feet of fracture followed welded seams or the heat-affected zone.

Age: Insofar as age of structure is concerned, there seems to be no correlation between age and the occurrence of brittle failure. In ships, this conclusion was found to be statistically valid.

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CLASSIFIED ABSTRACTS

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ELECTRICAL ENGINEERING

Abnormal Oscillations in Electric Circuits Containing Capacitance.

By N. H. KNUDSEN. (From *Acta Polytechnica, Sweden*, Electrical Engineering Series, Vol. 5, No. 1, 1953, 134 pages, 70 illustrations.)

IN electric circuits containing transformers or machines, e.g., power systems and voltage-metering circuits in such systems, certain abnormal oscillations may arise when a considerable amount of capacitance is present in the circuit. The capacitance may be located in capacitors, in cables, or in overhead lines. Two kinds of such phenomena are dealt with in this paper.

In the case of ferromagnetic resonance oscillations, the resonance frequency may be equal to the supply frequency (fundamental resonance), or to a multiple or a fraction of the supply frequency (resonance at harmonics and resonance at sub-harmonics respectively). These phenomena, being of a non-linear character, are analysed by approximating the magnetisation curve by a parabolic curve

$$I = c\,\Phi^m$$

where $m = 3, 5, 7$, or 9. Consideration may be given to additional linear terms of Φ or I.

As a result of the method of investigation developed, several sub-harmonic resonance cases are analysed and graphs are made up, showing the effective current in the sub-harmonic state as a function of the supply voltage and at different values of the damping resistance in the circuit. The results of earlier experiments are also given, and these agree fairly closely with the calculations. Some cases of resonance at harmonics are also analysed. Examples of applications of the theory are given.

The paper also deals with self-excitation of induction machines and synchronous machines. The principal question, which concerns the character of natural oscillations, is answered by examining the roots of the characteristic equation belonging to the system. The problem is illustrated by means of examples; a number of practical cases of different kinds is described, and the application of the theory to these cases is discussed. Finally, the results of several experiments and field tests in Sweden are briefly outlined.

ELECTRONICS

Magnetic Recording for Vehicular Research.

By G. K. GUTTWEIN and J. M. LESLIE, Jr. (From *Electronics, U.S.A.*, Vol. 27, No. 2, February 1954, pp. 154-159, 9 illustrations.)

MECHANICAL research and test work on the behaviour of vehicles and of the electronic equipment installed in such vehicles during road tests can be greatly simplified by the use of suitable recording equipment. Such equipment should record the signals picked up by mechanical-electrical transducers, should remain undisturbed by external shock and vibration, and should be capable of faithfully reproducing the stored information many times.

Magnetic recording seems suitable for such applications. However, conventional audio recorders of this type have four main deficiencies where the recording of stress, strain, shock, and vibration is concerned:— Few will record signals at a frequency as low as 20 cps, and none will record zero cps; faithful recording of complex waves is impossible, because of appreciable phase shift; amplitude variations are present in the reproduced signal, these being due to imperfections in the tape coating; and finally, such recorders will not function satisfactorily while being subjected to extreme shock and vibration.

The first three of these deficiencies can be eliminated by the use of an f-m carrier recorder system, while the last can be overcome by a reinforced, low-flutter tape transport mechanism. Under these conditions, magnetic tape recording becomes suitable for vehicular research and test work, and such a recorder is described is this article.

The recording portion of the equipment uses multiple tracks on a half-inch magnetic tape, and is capable of recording eight channels simultaneously Six of these channels are used for recording data, and employ an f-m carrier system with a frequency response from 0 to 1000 cps. The seventh channel is a direct high-frequency bias recording channel, with a response from 1000 to 10,000 cps, for voice recording, and accommodates a high-impedance microphone or other similar pick-up device. The eighth channel automatically records a tuning-fork timing signal. The recorder provides up to 15 minutes of continuous recording at a tape speed of 30 inches per second.

The reproducer head assembly is basically identical with that of the record head, except for the addition of a full-track erase head, for erasing the signals from all channels simultaneously, when desired. The playback speed can be equal to, one-third, or one-tenth, that of the recorder. Consequently, recorded phenomena can be decreased in frequency by one-third or one-tenth, if desired, so that frequencies of from 0 to 1000 cps can be reproduced on a standard ink recorder.

One of the most valuable features of magnetic recording equipment of this kind is that information stored on the tape can be repeated over and over again. Furthermore, it is easily adaptable to computing machinery and can also be employed for statistical evaluations, for which pulse counters, in connection with amplitude discriminators, have already been used successfully.

The equipment described in this article has so far been used in investigations pertaining to tanks, trucks, weapon carriers, railways cars, and guided missiles, and has apparently proved of great value.

FLOW MECHANICS

Turbulent Boundary Layers in Adverse Pressure Gradients.

By F. H. CLAUSER. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 21, No. 2, February 1954, pp. 91-108, 26 illustrations.)

ONE of the most challenging problems in fluid mechanics to-day is that of understanding the behaviour of turbulent boundary layers, particularly with regard to their separation or detachment. A great deal of technology is concerned with such devices as fans, compressors, turbines, pumps, aircraft, etc., and in almost all cases the limiting performance of these devices is determined by flow separation. The ultimate lift of a wing or the thrust of a propeller is determined by stalling, i.e., separation. Similarly, the maximum compression of

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an axial-flow fan and the maximum torque of a converter are limited by separation.

Near every solid surface immersed in a moving fluid, there is a layer of fluid retarded by friction. Most fluid mechanical machines are directly limited in their capabilities by separation of turbulent boundary layers. This separation is caused by the action of adverse or rising pressure gradients, retarding the fluid in the boundary layer, bringing it to rest, and forcing the outer stream to leave the surface and ride out over this stagnant fluid.

Despite the great technical importance of turbulent separation, knowledge of the action of pressure gradients on turbulent layers is poor. Firstly, no theory worthy of the name exists for any turbulent shear flow; secondly, although several empirical methods exist for predicting the effect of pressure gradients on turbulent boundary layers, experience indicates that none of them is reliable.

In this paper, an experimental study has been made of turbulent boundary layers in adverse pressure gradients, established in such a way that, for each layer, the profiles, when plotted in a set of universal co-ordinates, are of similar shape. A comparison is made with the corresponding set of laminar profiles. Results are presented for the effects on skin friction of Reynolds number, pressure gradient, and roughness. It is shown that boundary layers in moderately high adverse gradients will not exhibit what is termed downstream stability. A comparison is made of the present experimental results with conventional methods of predicting the effect of pressure gradients in turbulent boundary layers, and it is shown that agreement is poor.

GAS ENGINEERING

Accelerated Continuous Carbonisation by the "Rochdale" Process.

By T. NICKLIN and M. REDMAN. (From a paper presented at a meeting of *The Institution of Gas Engineers, Manchester*, March 12, 1954, 55 pages, 7 illustrations.)

THE Gas Industry has operated, over the past fifteen years or so, under rapidly changing conditions, which are still showing little tendency to stabilise. It has had to face substantial increases in the cost of raw materials, in labour and maintenance charges, and in the cost of new plant. Moreover, the delivery of new plant, although now improving, is still protracted, and is often the cause of inconvenience and the necessity to maintain uneconomic production plant in operation longer than is desirable.

In this paper, methods of gas production are reviewed in the light of production costs. The need to reduce these costs is shown and the contribution offered by integration of gas manufacturers is noted. Further reduction could be made if productivity could be increased from existing assets in the form of production plant.

Examination of existing gas-making methods has suggested that this could be achieved in the case of continuous vertical retorts, which constitute some 70% of the coal-gas capacity of the North Western Gas Board. This paper describes a new technique of coal carbonisation, and deals in some detail with the results which have been achieved on pilot scale trials. Considerably increased speeds of carbonisation are shown to be possible, more than double the conventional rates being obtained.

The effect of this increased productivity is examined in relation to production costs, capital expenditure, size and quality of coal, coke quality, and plant flexibility, and the conclusion is drawn that the process shows promise of yielding the desired reduction in production costs and of increasing flexibility. In addition, the process further indicates the possibility of blending of coal, with a view to reducing costs and making use of lower grade coals, and the production of a more suitable domestic smokeless fuel.

IRON AND STEEL

The Influence of Low-Temperature Treatment on the Mechanical Properties of Heat-Treated High-Speed Steel.

By V. I. MAKAROV. (From *Vestnik Mashinostroyenia, Russia*, Vol. 33, No. 12, December 1953, pp. 63-66, 9 illustrations.)

SAMPLES of high-speed steel (composition 0·74% C; 4·28% Cr; 18·73% W; 0·26% V; 0·48% Mo) were quenched from various temperatures between 1260° and 1320° C and tempered at various temperatures between 50° and 650° C. The special subject of this study was the influence of subsequent low-temperature treatment at −78° C on the mechanical properties of the samples. These were determined by bending and torsion tests.

The results show that bending strength goes up with tempering temperature from 200 kg/mm² without tempering to 300 kg/mm² at 550° C. Low-temperature treatment increases both values to 250 and 380 kg/mm² respectively. The influence of tempering temperature on torsion strength is equally pronounced, but not that of low-temperature treatment. In all cases, strength falls rapidly and ductility rises equally rapidly beyond a tempering temperature of 550° C.

In general, it has been observed that low-temperature treatment greatly increases the plasticity of the steel. Without cold treatment the steels show a brittle failure when tested in bending. After low-temperature treatment plastic deformation precedes failure. This property is expressed by the residual deflection. For steels tempered at about 550° C, the residual deflection is increased about twelve times by low-temperature treatment, whilst the ultimate strength increases in some cases by 30%. Also of interest is a fairly gradual variation of the shear modulus of the steel with tempering temperature for steels subjected to low-temperature treatment.

The study included examination of chemical and crystallographic changes due to tempering and subsequent low-temperature treatment.

MARINE ENGINEERING

Marine Shafting Alignment.

By G. YELLOWLEY and J. E. RICHARDS. (From a paper presented at a meeting of the *North-East Coast Institution of Engineers and Shipbuilders, Newcastle-upon-Tyne*, March 12, 1954, pp. 343-376, 17 illustrations.)

IN large marine installations, the criterion of shafting alignment during installation is the fairness of the couplings, both between faces and periphery, before fitting the coupling bolts, while the alignment of the crankshaft main bearings is judged by crank-web deflections. These criteria, which are accepted by the classification societies, subject to satisfactory trials on completion, have been in use for many years and have given general satisfaction. As a result, however, of the experience gained in checking alignment with a new technique, it is believed that there is need in certain cases for a review of the above criteria, especially with regard to crank-web deflections in engines of high power, requiring comparatively long and, to some degree, flexible bedplates.

In this paper, a brief account is given of a method in general use for installing propeller shafting and for setting an engine bedplate to align the crankshaft with the propeller shafting. This is followed by a discussion of the events which have led to the need for modification of the above procedure, and a description of a simple technique to enable alignment to be checked during construction, installation on board ship, and in service under loaded and light ship conditions. Alignment readings obtained during these stages are given, together with readings taken during the investigation of service difficulties, in which misalignment had been suspected.

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In addition, results are given of calculations, made by the staff of the British Shipbuilding Research Association, of the variation in the loading of the shaft bearings in a 17,000-ton d.w. diesel-engined tanker, with wear-down of the stern bush. The significance of the results is discussed with regard to such factors as the effect of propeller forces, the allowable wear-down of the stern bush, and the possibility of lateral vibration of the shafting occurring in service. It is concluded that the aim in design should be to provide sufficient flexibility, so that the bearing loads on the after plummer blocks do not change appreciably with wear-down of the stern bush.

METALLURGICAL ENGINEERING

Effect of Various Additions, Hot Working, and Heat Treatment on the Magnetic Properties of Low-Carbon Steels.

By M. MARKUSZEWICZ and M. GROYECKI. (From *Prace Instytutów Ministerstva Hutnictwa, Poland*, No. 2, 1953, 32 pages, 50 illustrations.)

THE applications of low-carbon steel in electrotechnics are described in this paper, together with the effect on the magnetic properties of various factors, such as content of additions, grain size, orientation of crystalline particles, and mechanical strains.

The authors have examined a steel from 4 melts from a basic open-hearth furnace, containing 0·03% C, and a steel from 32 melts from a 15-lb electric induction furnace. When testing the effect of heat treatment, it was found that, for large sections of from approximately 4 to 8 in. in diameter, magnetic properties depend entirely on the zone segregation. In the case of thin sheets, improved magnetic properties are connected with the partial decarburisation during annealing and rolling. The effect of heat treatment on magnetic properties was tested on sheets which were pickled and covered with scale (by normalising) and then box annealed. Gaseous atmospheres of hydrogen and nitrogen, dry and wet, were used. It was found that annealing, carried out in high temperatures (about 2000 to 2300° F) contingent on the atmosphere used, may have a detrimental influence on the magnetic properties, owing to the increased content of nitrogen and oxygen in steel. These phenomena are particularly apparent when annealing is effected in a nitrogen atmosphere or in sheets covered with scale.

Sheets and rods, pickled and pack-annealed at temperatures of 2000° and 2200° F, showed a considerable increase in coercive force as a result of steel ageing caused by a higher nitrogen content in the metal, even though they had a low coercive force immediately after the treatment.

When testing the effect of additions, it was found that low-carbon steel, containing about 0·6% Si and up to 0·25% Al, does not show any noticeable change in magnetic properties arising from ageing. The addition of 0·2% Si and 0·2% Al was found to be the most suitable.

METALS CORROSION

Corrosion Studies on a Model Rotary Air-Preheater.

By G. G. THURLOW. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, March 1954, 8 pages, 8 illustrations.)

IT has been established that the corrosion occurring in air heaters of power-station boilers is generally due to the action of sulphuric acid condensing from the flue gases. Tests on full-scale installations using, among other instruments, air-cooled metal probes, have provided quantitative data on the relation between corrosion and surface temperature, and have confirmed that there are several factors, especially dust loading in the gases, which influence the degree of corrosion. Furthermore, laboratory investigations, under controlled conditions, have shed more light on the mechanism by which corrosion occurs in both clean gases and in the presence of carbon smokes.

These earlier laboratory investigations employed a system in which a steel hemispherical surface of limited area was inserted into laboratory gases containing sulphur trioxide, for periods up to one hour, and attention was focused on the relative importance of dew-point and metal temperatures. It was believed, however, that as the conditions in such experiments departed considerably from those in actual practice, interpretation of the results with respect to full-scale practice was correspondingly limited.

The present series of tests discussed in this paper has been carried out to repeat this earlier work, under conditions more representative of practice, and to extend it in the light of later experience. Use was made of a model rotary preheater for fundamental heat-transfer studies. Apart from aerodynamic considerations, this also has the advantage over a small probe in that its design facilitates the removal and analysis of corrosion products at various intervals during a run.

The acid dew point of the combustion gases used varied from 240 to 320° F and maximum corrosion occurred at surface temperatures within the range of 215 to 240° F. The results confirm previous conclusions as to the influence on corrosion of the acid dew point and of the sulphur trioxide content of the gases.

NUCLEONICS

Nuclear Reactors and Power Production.

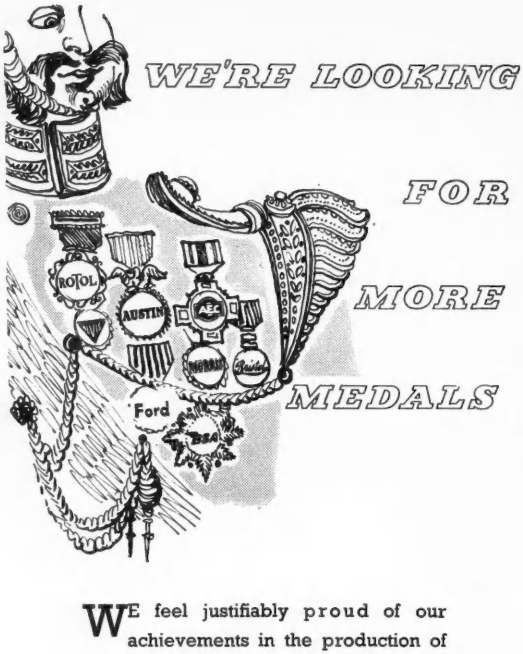
By SIR CHRISTOPHER HINTON. (From a lecture presented at a meeting of *The Institution of Mechanical Engineers, London*, February 26, 1954, 14 pages, 23 illustrations.)

THIS lecture deals with the design and construction of nuclear reactors, and particularly of types suitable for the generation of power. A detailed description is given of the British Experimental Pile (BEPO) at Harwell. This is a typical " thermal " reactor on a small scale, using natural uranium as a fuel and graphite as a moderator ; it is air-cooled and the shielding and control arrangements illustrate general practice. An account follows of some of the engineering and construction problems encountered in the erection of the Windscale piles, and the solutions achieved.

The problems involved in designing power-producing reactors are discussed. The safety aspect of design is considered and the influence of the coolant is described ; certain types of reactor can be designed to be inherently safe, even in the event of a coolant failure, but with others there is the risk of reaching a supercritical condition, and the effect of this is described.

The possible reactors may be divided into two groups, i.e., those which use " thermal " neutrons and are similar in principle to BEPO, and those which use " intermediate " or " fast " neutrons, and have a much smaller core size. Within each group are alternatives provided by differences in fuel, moderator, and coolant. Several of these are reviewed, with general indications of their size, and some of the more detailed problems associated with their design are considered.

Prospects for the large-scale development of nuclear power are discussed, and it is argued that the replacement of coal-fired boilers by nuclear reactors as the heat source at power stations should, before many years have passed, be economically sound, and is justifiable on the grounds that they would help to reduce the recurrent shortage of coal. A possible national scheme is outlined, in which thermal reactors would be built in the first stage ; these would produce supplies of fissile material as well as power, and this material would later be used in " breeder " or " converter " reactors in the second stage ; these reactors should be self-sustaining after the initial charge.



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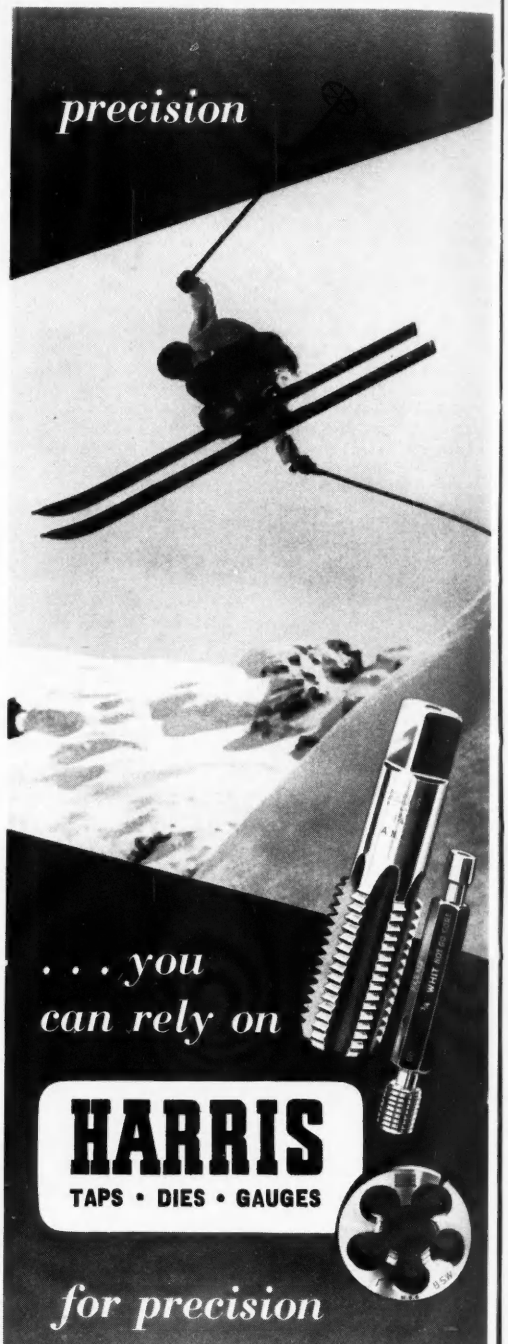

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ROCKET PROPULSION

Erosive Burning of Some Composite Solid Propellants.

By L. GREEN, JR. (From *Jet Propulsion, U.S.A.*, Vol. 24, No. 1, January/February 1954, pp. 9-15, and 26, 15 illustrations.)

THE term " erosive burning " is used to indicate the dependence of the burning rate of a solid propellant upon the velocity of gas flow parallel to the burning surface. Although its influence and importance are now recognised and a theoretical study of the phenomenon has already been presented, the simplifying assumptions presented therein render the theory semi-quantitative at best.

No practical method of determining the instantaneous burning rate of a solid propellant grain is at present known. Accordingly, the present study employs the standard partial-burning technique, in which the propellant grain is extinguished after burning for a recorded interval of time, and the amount of propellant burned off at various points along the grain is measured. The gas pressure and velocity at these points are then calculated, using the time-average dimensions of the flow channel. During some of the tests, the cross-sectional area of the flow channel increased significantly. For this reason, use of the geometric time-average area was required in the calculations. In the most extreme cases of area change during burning, the diameter of the grain perforation almost doubled, and comparison of the mass velocities computed from both the arithmetic and geometric mean values of cross-section of flow channel revealed differences approaching 25%.

In this paper, experimental data on the erosive burning of several composite solid propellants are reported and discussed. The data appear to be best correlated in terms of a reduced mass velocity. At low Mach numbers, this correlation becomes equivalent to several widely used forms employing linear velocity. It is found that the erosive effect is greater in slow-burning propellants than in fast-burning ones, an observation which is consistent with previously reported data for various double-base propellants.

The existence of an apparent " threshold velocity " for erosion is tentatively attributed to the failure of the one-dimensional idealisation to represent true flow conditions obtaining at the fore end of the grain, but it is emphasised that more comprehensive studies of the phenomenon of erosive burning will be required, in order to resolve the threshold velocity question. In this connection, X-ray motion pictures of rocket motors during firing have been under discussion for at least ten years, as a method of determining burning rates, but apparently no data have been obtained by this technique. High-speed photographic recording of short-duration, interrupted-burning tests in a two-dimensional, transparent-walled chamber might prove to be more practical.

THERMODYNAMICS

Heat Transfer by Convection from a Hot Gas Jet to a Plane Surface.

By K. P. PERRY. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, March 1954, 8 pages, 9 illustrations.)

MANY industrial processes employ hot gas or flame jets in heating systems, in which a proportion of the heat is transferred by convection when the gases impinge on a surface. The efficiency of these heating methods cannot easily be estimated, owing to the lack of experimental data which can be used in calculations.

Most of the previous experimental work applicable to these problems has been confined to parallel gas flow over plane surfaces which are small when compared with the gas stream and with small temperature differences between the gas and surface. In many applications, where flame or gas jets are used, the surface is larger than the gas stream and the gases usually impinge on it at an angle.

The first object of the present experiments was, therefore, to verify the recommended expression for parallel flow over an extended range of temperature and velocity, and then to measure the effect of changing the angle of impingement on the heat transfer. The second object of the experiments was to investigate the heat transfer across an expanding hot gas jet at various angles and distances downstream, and to seek, in the results so obtained, a relationship of this nature.

Measurements have been made of the heat transfer from air jets, with temperature differences of up to 750° F and velocities of up to 250 fps, impinging on a plane surface at various angles. It has been found that, for flow parallel to the surface, the recommended mean formula, in terms of the Nusselt number Nu, the Reynolds number Re, and the Prandtl number Pr, $Nu = 0{\cdot}0356\ (Re)^{0{\cdot}8}\ (Pr)^{0{\cdot}33}$, is still valid over this extended range of velocity and temperature. For flow perpendicular to the surface, the formula $Nu = 0{\cdot}1810\ (Re)^{0{\cdot}7}\ (Pr)^{0{\cdot}33}$ expresses the results, if the velocity and temperature are calculated from free-jet formulae. A series of multiplying factors has been obtained for this formula for angles of gas impingement down to 15 deg, at which angle the heat transfer is approximately half that at 90 deg.

Where a gas jet impinges on a relatively large plane surface, it has been found that the heat-transfer contours for any one angle are identical for all jet sizes at all cross-sections situated more than ten nozzle diameters downstream. This result holds even where the temperature of the gas at the orifice exceeds that of the ambient air by more than 930° F.

This extension of the jet similarity theory to impinging gas jets provides a simple method of calculating the total convective heat transfer from such a jet.

X-RAY ANALYSIS AND TESTING

A New X-Ray Microanalyser Camera.

By L. v. HÁMOS. (From *Acta Polytechnica, Sweden*, Physics and Applied Mathematics Series, Vol. 2, No. 7, 1953, 68 pages, 46 illustrations.)

THE special technique of X-ray image-spectroscopy which is the subject of this paper is based on the property of cylindrically bent crystal surfaces of producing true monochromatic images from layers emitting X-rays. The latest developments in this technique are presented and, to facilitate the understanding of the results obtained, a complete theoretical background and a review of some of the author's earlier results are included.

A detailed description of the apparatus is given, including a description of a new X-ray microanalyser camera, which may also be called an X-ray microspectrograph, owing to its ability to produce X-ray spectra from small samples. There is also a description of crystal-bending techniques and of a special X-ray tube giving high primary intensities for the excitation of the fluorescent radiation of the sample.

Some tests of the image-forming quality of the camera are described, and these are followed by details of some typical applications. The non-destructive determination of the thickness of surface layers ranging between $0{\cdot}2\mu$ and 3μ is demonstrated, and the micro-analysis of alloys is described, the volume of the sample involved in the analysis being of the order of 10^{-8} cm^3. In addition, the topographical analysis of surfaces is described as a " chemical mapping " of the concentration of the element corresponding to the X-ray image in question.

In the final discussion, the method is compared with other X-ray techniques. The list of possible applications includes the combination of the microanalyser camera with self-balancing measuring devices, for the rapid evaluation of fluorescence analysis data.

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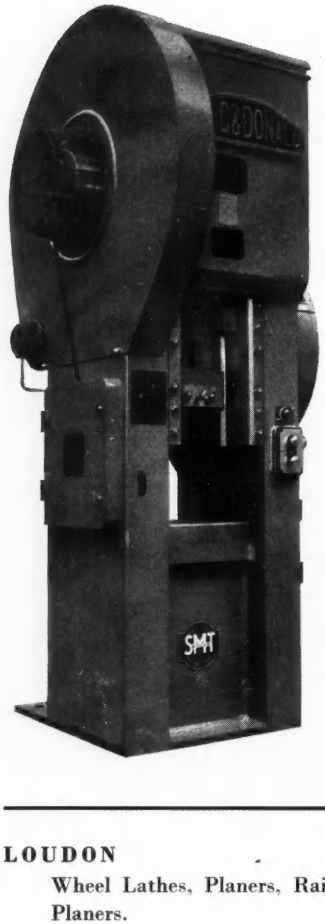

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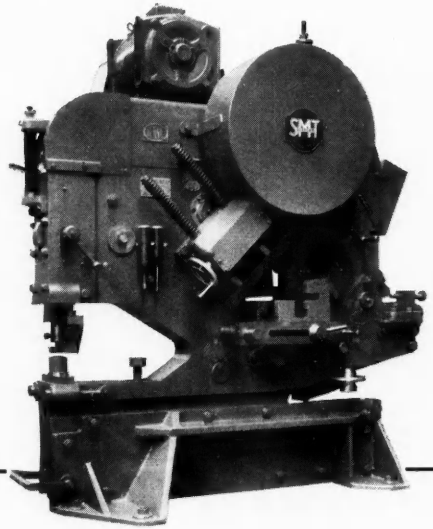

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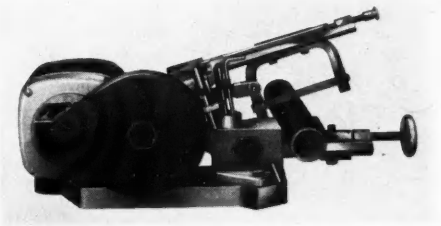
BRITISH INDUSTRIES FAIR, 1954

The 33rd British Industries Fair, some exhibits of which are previewed in the following pages, will take place this year between May 3 and May 14. The engineering, building and heating, electrical, and hardware sections will be located at Castle Bromwich, Birmingham, while other sections, covering chemicals, instruments, optical and photographic goods, office appliances, etc. will be housed at Olympia and Earls Court, London. A further selection of exhibits will be reviewed next month.

What is claimed to be the smallest, lowest-priced power saw in the world will be exhibited by **W. Kennedy Limited,** of West Drayton, Middlesex. Precision-engineered to cut a 0·010-in. slice, the new power hacksaw (illustrated) is only 22 in. in length × 10 in. in width × 7½ in. in height, and weighs 40 lb. The machine is supplied complete with a ⅛-hp motor, but alternatively a non-powered version, with a 4½-in. V-pulley, for use with the purchaser's own drive, can be supplied.



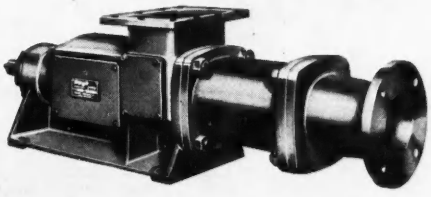
The maximum capacity of the saw is as follows :— Square bar, 2 in. × 2 in. ; round bar, 2 in. diameter ; steam and gas pipe, 1½ in. bore ; tube, 2 in. o.d. ; angle, 2 in. × 2 in.

Among other items, **Saml. Denison & Son Ltd.,** of Leeds, will be exhibiting the following :—

A 10/15-ton and a 30/50-ton universal testing machine, both of improved design ; tensile and universal testing machines of 5·5 to 6·7 tons capacity ; a miniature high-temperature creep-testing machine ; a new heavy-duty torsion-testing machine ; a compression and transverse-testing machine, for bricks, concrete specimens, etc., of 150 to 200 tons capacity ; a fabric-testing machine, with constant rate-of-load and constant rate-of-traverse mechanism ; a Blake-Denison totalising belt conveyor weighing machine, incorporated with a moving conveyor unit ; and several of the latest design of suspended weighing machines.

In addition, the Denison patented equilibrium-controlled mistake-proof, two-colour, tape and ticket-printing mechanism, as used with weighbridges and other types of weighing machines, will be exhibited.

Demonstrations of their DM12 Mono Pump (illustrated) for handling dry materials by pumping a powder in a piped circuit within the confines of the stand, will be given by **Mono Pumps Limited,** of London, E.C.1. The demonstration will show how a small quantity of injected air is used to fluidise the powder, but it is emphasised that the use of such air is kept within very low limits and that it is not used for blowing powder through the pipe. A 5-hp motor is sufficient to cover the full range of duties of this pump, and capacities may be said to range from 3 to 5 tons per hour, depending on the density of the powder being handled.



As a pumping accessory, their new automatic " snort " bypass will also be shown. This item is of particular application to mine pumping, where the flow of water to the suction side of the pump is often intermittent.

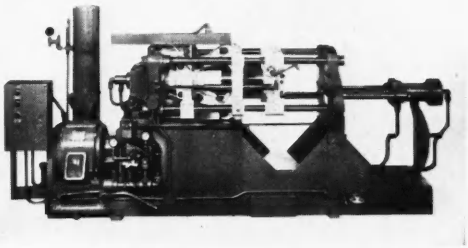
Examples of British-made Leeds & Northrup " Micromax " indicators, recorders, and controllers, together with a selection of heat-treatment furnaces, will be exhibited by **Integra, Leeds & Northrup Ltd.,** of Birmingham.

The range of instruments exhibited will include " Micromax " strip-chart recorders and recording controllers, indicating controllers, electrically operated proportioning control systems, and examples of switchboard type and cabinet-mounted type industrial indicators, portable potentiometer indicators, and various ancillary items, such as thermocouples, compensating cable, etc.

Examples of furnaces will include electrically heated gas carburising furnaces, furnaces for steam treatment, and the " Vapocarb-Hump " hardening furnace, incorporating the " Vapocarb " atmosphere.

The following machines will be exhibited by **Dowding & Doll Ltd.,** of London, W.14 :—

Two " Dowding " automatic fast-cycling injection-moulding machines ; a " Lester " L-½-4 injection-moulding machine ; a " Westminster " power-operated injection-moulding machine ; a " Lester " HHP-1-CC die-casting machine ; a " Lester " HHP-2-XE die-casting machine ; and a " Hare " 7½-ton hydraulic power-operated press.



The " Lester " machines are built under licence in Great Britain by arrangement with the Lester Engineering Company, of Cleveland, Ohio, the HHP-2-XE die-casting machine (illustrated) being a new model.

A representative selection of drafting machines, ranging from the small student's machine to the " Major," which is capable of covering boards up to 50 ft in length, will be exhibited by **The Mavitta Drafting Machines Ltd.,** of Birmingham.

An entirely new isometric drafting machine, operating on the pantagraph system, will be exhibited for the first time. With this machine, very little training is required to produce isometric drawings of a high standard.

A range of drawing stands and mathematical scales will also be shown, together with the new " Master " drafting machine, which is now in full production.

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A.E.G. Publications

The main items to be exhibited by **G.W.B. Furnaces Limited,** of Dudley, Worcs., will be the " Autolec " electrode-type steam raisers and water heaters, and, in particular, the " Powermaster " oil- or gas-fired boiler (illustrated).

The " Powermaster " is the first completely self-contained, packaged boiler of its type to be available in Great Britain, and is suitable for operating on all types of fuel oil. The boiler is available in a wide range of sizes, from 517 lb/hr of steam or 502,125 B.T.U./hr for hot water, to 17,250 lb/hr of steam. The equipment is supplied ready interpiped and interwired, and no special foundations or chimney stacks are required. The " Powermaster " is completely automatic in operation and is entirely smoke-free.

In addition to the comprehensive range of ball, roller, and thrust bearings, American-type roller assemblies, heavy-duty roller bearings, etc. to be exhibited by **Pollard Bearings Limited,** of Knottingley, Yorks., will be their new range of clutch withdrawal bearings, specially designed for clutch throwout duties, and the Pollard water pump spindle bearings, which considerably simplify the mounting of automobile fans and pumps.

Also on exhibition will be a " Max-Load " bearing manufactured by Pollard for a rolling-mill breakdown in Holland; this bearing measures $17\frac{1}{2} \times 11\frac{7}{8} \times 2\frac{1}{2}$ in., and is the largest yet manufactured in this range of Pollard bearings.

A comprehensive variety of products will be exhibited by **Rubery, Owen & Co. Ltd.,** of Darlaston, South Staffs., and member companies of the Owen organisation, including caravan and light trailer axles, complete with wheels and tyres; agricultural machinery components and assemblies; hydraulic jacks, valves, etc.; liquefied petroleum gas cylinders; pressed-steel V-belt pulleys; arc-welding electrodes and welders' accessories; adjustable steel shelving, clothes-locker units, and steel office furniture; non-ferrous sand-castings, "Hilchil" phosphor-bronze bars, aluminium gravity die castings, and shell moulded castings; and bolts, nuts, and " Evertite " locknuts.

In addition, a model E2-20/3W battery electric fork truck, one of the extensive " Conveyancer " range, will be on exhibition. This 2000-lb three-wheel truck is a re-styled development of earlier models; it is fitted with a 9-ft lift mast, and incorporates full free lift, permitting elevation of the load without extension of the mast.

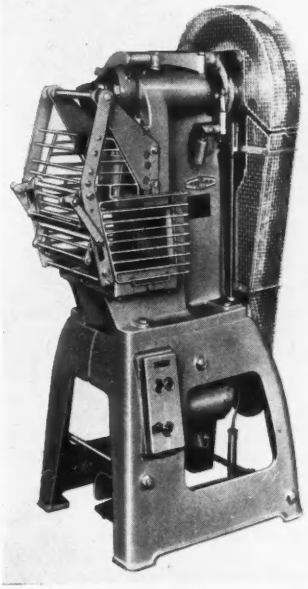
Among the products to be exhibited by **William Crosland Ltd.,** of Bredbury, Cheshire, will be their patented blanking and piercing tools, the purpose of which is to provide a quick, cheap, and efficient method of tooling short to medium runs in steel, non-ferrous, and non-metallic materials.

These tools consist of special steel cutting edges set in a synthetic laminated material of high tensile strength. They can be used to blank and pierce in one operation, or as follow-on tools, when blanking and piercing in one operation is not advisable. They have universal die clearance within wide dimensions on linear dimensions, normal clearances on punches, and are cheap to maintain, recondition, and modify.

Examples of architectural ironwork, rust-proofed by the Sherardizing process, will be exhibited by the **Zinc Alloy Rust-Proofing Co. Ltd.,** of Wolverhampton, at their stand, which will form a technical information bureau, where visitors will be able to obtain full particulars of the process, its cost, and details of the uses to which it can be put in the various trades.

It should be remembered that the Company does not manufacture architectural ironwork, but specialises in carrying out Sherardizing for the actual makers of such items as steel casements, metal trim, electrical conduit, iron door furniture, nails, nuts, bolts, washers, gate fittings, etc.

The most recently designed power press in the range of equipment to be exhibited by **Humphris & Sons Ltd.,** of Poole, Dorset, is their " Pressmaster " EP.10A 10-ton endwheel press (illustrated). This model, which meets all the requirements of a small, general-purpose power press, is in quantity production, and deliveries are generally very favourable.



Other equipment to be exhibited will include their Model CS.300 inclinable self-centering coil stand, representative of a new range of coil-handling equipment; their Model CD.1000 combination decoiler, for handling coils up to 1000 lb in weight and 16 in. in width; their Model CC.10/F double roll feed press; their Model CC.10/DF endwheel dial feed press; and their Model IC.20/F double roll feed press, which is a 20-ton inclinable press of extremely heavy construction.

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"Rapid" products include: Electric and non-electric Pulleys and Pulley-type Separators, Swarf Separators, Drums. Stationary and Vibrating Chutes for Wet and Dry processes, Overband Separators and Extractors, Welding Clamps; Floor Sweepers, Plate and Textile Magnets. Electromagnetic Clutches, Brakes, Lifting Magnets, Suspension Magnets; Heavy Media Separators, Feebly Magnetic Ore Separators, Percolators for the Ceramic Industry.

RAPID MAGNETIC MACHINES LIMITED

LOMBARD STREET, BIRMINGHAM, 12 'Phone: VICtoria 1137 P.B.X. 'Grams: "Magnetism, Birmingham"

A wide range of tube-bending machinery, covering almost unlimited general-purpose applications, and in particular catering for the production of exhaust pipes for commercial vehicles, cars, etc., cycle handlebars, tubular furniture, transformer bends, etc., will be exhibited by **Hilmor Limited,** of London, N.1.

The motorised non-mandrel bender, type H.M.4/B (illustrated), which incorporates the Hilmor patent pressure indicator, will be shown for the first time. This is a general-purpose machine, designed to produce good-quality bends up to 180 deg in non-ferrous tubes up to 5 in. in diameter, in light-gauge ferrous tube up to 4½ in. in diameter, and in heavy-gauge gas and steam tube up to 4 in. nominal bore, on radii equalling approximately 3½ diameters.

In addition to a wide range of industrial motors and generators in a variety of types, and fractional horsepower motors, including split-phase, capacitor-start, etc., **Higgs Motors,** of Witton, Birmingham, will be exhibiting a new range of totally enclosed fan-cooled motors, designed in accordance with British Standard CN (Ele) 6814, and an enlarged range of single- and three-phase self-regulating generators, for operation without the use of an automatic voltage regulator.

Among the extensive range of products to be exhibited by **Westinghouse Brake & Signal Co., Ltd.,** of London, N.1, is a barrier machine, designed as an alternative to the heavier type of entrance or level-crossing gate.

The pneumatic equipment marketed by the Company will be amply exemplified, as also will be rectifier units, and small d.c. power-supply sets catering for supplies up to 7 or 8 kW. A live demonstration of the " Dalic " plating process will be a prominent feature of the rectifier section, and will also incorporate a small lathe, powered by a d.c. motor and a magnetic chuck, both deriving their direct current from a Westinghouse " Westalite " transformer/rectifier set.

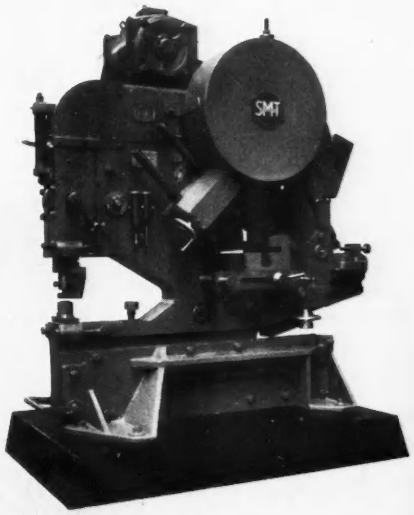
The new " Westruk," type 960 (illustrated) for hangar maintenance, apron servicing, and aircraft engine starting will also be exhibited. This transportable equipment can be easily moved by one man and provides 500 A d.c. for maintenance and apron servicing and a peak of up to 2000 A for engine starting.

An interesting range of seating and steel equipment for office and works will be exhibited by **Evertaut Limited,** of Birmingham. A prominent exhibit will be a new design of office chair, containing a number of refinements, some of which are technical and utilitarian, while others have been incorporated for neatness and appearance. This design has recently been accepted by the Council of Industrial Design.

Another item of interest will be the showing of an all-colour sound version of Evertaut's three-dimensional film dealing with storage shelving.

Machine tools to be exhibited by **Murad Developments Ltd.,** of Stocklake, Aylesbury, will include four models of the Murad high-speed capstan lathe, i.e., ¾ in., 1 in., 1A, and 1B. In addition, there will be displayed two models of the Murad dustless grinder, the 8-in. for offhand tool grinding, and the 16-in. for production grinding, respectively.

Among other exhibits of the **Scottish Machine Tool Corporation Ltd.,** of London, S.W.1, will be featured the " Bennie " splitting shears and punch (illustrated), with bar, angle, and tee bevel cropper, and, where specified, notcher.



Another exhibit will be the SS.100/16 press, with a capacity of 100 tons. In this press, the width between sides is 16½ in., the stroke is 8 in., the number of strokes per minute is 45, and the driving motor is 10 hp and operates at 1450 rpm.

A spring balance, 12 ft in height and itself weighing more than 12 tons, designed to take weights up to 200 tons, will be the highlight of exhibits of **Geo. Salter & Co. Ltd.,** of West Bromwich. This machine is an outsize development of the Company's well-known crane weigher.

Other exhibits will include various examples of crane weighers and platform machines, designed primarily for industrial weighing, together with spring balances for every weighing purpose, including domestic, personal, medical, commercial, and agricultural. Springs, roller bearings, grey iron castings, retaining rings, and examples of the " Salterpak " method of prepackaging (designed to protect all types of goods during lengthy storage periods) will also be displayed.

Rectangular Pattern

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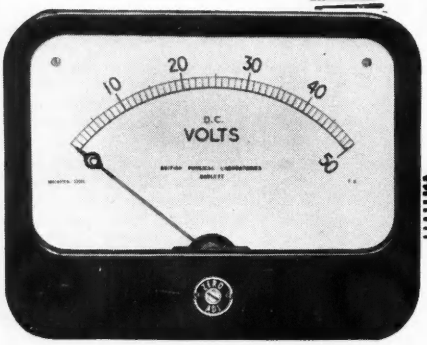

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Two entirely new, totally enclosed electrode steam boilers, to be known as the "Stanmore" and the "Kenton," will be exhibited by **Bastian and Allen Limited,** of Harrow. These boilers will be available for loadings of 30 and 70 kW, with outputs of 100 and 230 lb of steam per hour, respectively.

In addition, there will be displayed a standard Bastian electrode steam boiler, complete with patented modulator and control panel, an electrode hot water boiler for space heating and thermal storage plant, an electric air heater for grain drying and plenum heating, and a steam jet cleaner (illustrated). This equipment, which is rated at 20 kW, is used for cleaning and degreasing in the motor, aircraft, food, and other industries.

A wide range of automatic temperature control equipment, including "Satchwell" thermostats for the control of space-heating, air-conditioning, and domestic apparatus, will be exhibited by **The Rheostatic Company Limited,** of Slough, Bucks.

Also featured will be examples of various motorised valves for the control of steam, high-pressure, and low-pressure hot water, in "on-off," modulating, and spring-return types, together with a number of new sizes of valves, to make the range even more comprehensive. Other exhibits will include primary firing controls for automatic boilers, mechanical stokers, and oil and gas burners. Associated with these controls will be a number of protective devices for gas and oil firing, including photo-cell electronic flame-failure equipment for oil burners.

In addition to exhibiting a continuous dryer for barrel-plated parts and a range of EFCO-UDYLITE perspex plating barrels, **Electro-Chemical Engineering Co. Ltd.,** of Weybridge, Surrey, will give working demonstrations of "Zeromist," a new development for chromium plating, which, when added to existing chromium-plating baths, has the following advantages :—

It completely eliminates spray from chrome baths, so that fume extraction, with consequent loss of chromic acid, is not required. It reduces the surface tension of the solution, thereby cutting drag-out losses. It does not adhere to racks, is completely stable, produces no break-down products, and has absolutely no deleterious effects on chromium plating.

An entirely new range of steel desks and tables, designed on the unit principle, in which over 300 varieties of arrangement can be built from 17 inter-changeable units, will be exhibited by **G. A. Harvey & Co. (London) Ltd.,** of London, S.E.7. In addition, there will be a comprehensive selection of filing cabinets, steel plan cabinets, card-index cabinets, cupboards, clothes lockers, stationery cabinets, waste-paper tubs, book and letter racks, letter trays, adjustable storage bins, and shelving.

In addition to steel equipment of this type, the Company will be exhibiting a wide range of their heavier products, including heavy steel plate work, perforated metals, woven wire, wirework, sheet-metal work, etc.

Examples of its contributions to marine engineering and of equipment of all types for ships will be exhibited by **The General Electric Company Ltd.,** of London, W.C.2. Although the Company's services to ship-building will form the principal theme of their exhibits, many of the items selected are, however, of wide industrial application.

The field of auxiliary electrical power for ships will be represented by a 550-kW turbo-generator set, and by examples of G.E.C. marine motors for d.c. and a.c. supplies, while main and group switchboards, as installed in ships using alternating current for their auxiliaries, will show typical layouts of fully enclosed and protected switchgear in cubicle-type boards.

Other features will include exhibits of luminous call and fire-alarm systems, galley equipment for a.c. and d.c. supplies, lighting equipment and accessories, telephones, and fans, including "Aerofoil" fans and the new "Maxcess" pattern exhibited by **Woods of Colchester Limited.**

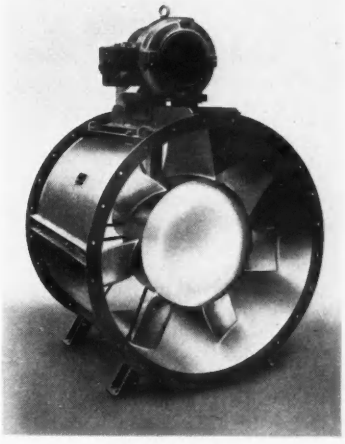
The attractive colour finishes obtainable with copper and its alloys will be used to good effect on the stand of the **Copper Development Association,** of Radlett, Herts., as the entire surface of the main stand structure will be covered with seven-inch square tiles of copper, brass, nickel silver, and gilding metal. Included in the design of the stand is a small projecting screen, also faced with metal tiles, while five display recesses will contain photographs of applications of copper and copper alloys.

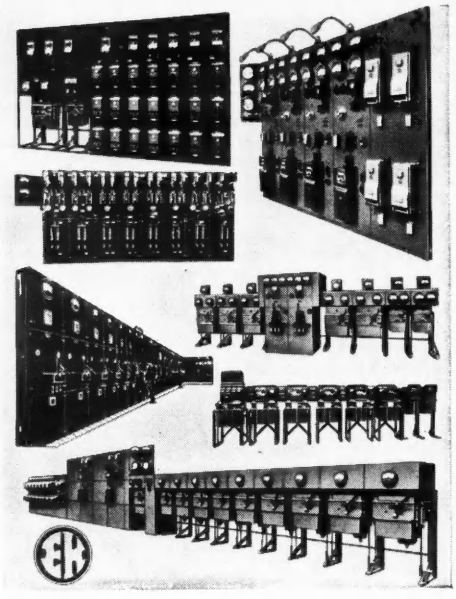
Also on the stand will be some striking examples of uses of copper and copper alloys, and a full range of the Association's excellent free publications.

An exceptionally wide range of fans of all types will be exhibited by **Keith Blackman Limited,** of Tottenham, London, including axial fans, window fans, air circulators, high-temperature-type bifurcated fans, marine-type fans, etc.

The "Tornado" 33-in. diameter trunnion-mounted marine-type axial fan, and the "Tornado" 16-in., type APA, propeller-axial fan will be exhibited for the first time. The former type is said to represent the latest development in marine ventilation equipment, while the latter has been designed for exceptionally quiet operation under free-air or light-resistance conditions.

The illustration shows their industrial fan, type AFX, of 48 in. diameter.





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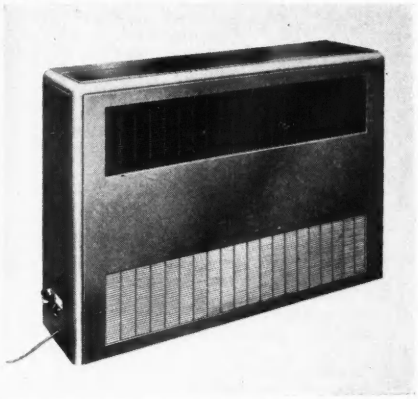
The chief new exhibit of the **Metallizing Equipment Company Ltd.,** of Chobham, Woking, will be the Sprabond Wire Process. The use of Sprabond wire —essentially pure molybdenum in a form suitable for metallizing use—has expanded rapidly since its introduction. At that time it was recommended primarily as a bonding coat material which simplified and speeded up surface preparation for most metallizing applications.

Since its introduction, however, many other interesting possibilities of application for this material have been indicated. Details of these will be available at the Company's stand.

In addition to their standard range of products, including heating, ventilating, cooling, dehumidifying, and general air-conditioning equipment, **F. H. Biddle Ltd.,** of London, will be exhibiting a new " Vectair " floor-type room cooler (illustrated). This cooler is electrically operated and incorporates propeller fans, as opposed to the current model, which uses a centrifugal fan system.



Other Biddle products undergoing tests at the moment, and which may be ready in time for the Exhibition, include a verandah-type air-conditioning unit for tropical use, a 7½-ton capacity air conditioner, a new type of adjustable ventilation grille, and a new range of unit heaters.

The Engineering Components Division of **Dunlop Special Products Limited,** of Birmingham, will be exhibiting a complete range of engineering rubber products illustrating the precision in dimension and performance achieved by the close control of design, rubber compounding, and moulding. The range includes flexible couplings, anti-vibration mountings, and a selection of products designed to suit the specific requirements of customers.

The flexible transmission couplings include the D.S.P. barrel-type for fractional horse-power drives, and the disc-type coupling for drives up to 96 hp per 100 rpm. The D.S.P. segmental coupling for very large horse-power drives will also be featured. The anti-vibration mountings cater for applications from the smallest instrument to the heaviest machinery, and include the insulation of large machine foundations.

The range of products designed to suit customers' requirements will include hydraulic and oil-retaining seals, load-measuring capsules, flexible clutches, diaphragms, flexible waveguides for radar equipment, etc., all of which demonstrate rubber as an engineering material of high quality and precision.

A wide range of industrial goods including hoses, rubber-covered rollers, silicone rubber products, and flexible pipes for hydraulic actuation, will be shown by the General Rubber Division of the Company, while the belting division will have a representative display of their products on the stand, e.g., flame-proof belting for mines, and transmission belting. There will also be a display of " Fortiflex " containers.

The " Eclipse " exhibit of **James Neill & Company (Sheffield) Limited,** of Sheffield, will feature two distinct sections. The first section will be devoted to their wide range of tools, including hacksaw blades and frames, and many other hand and precision tools. To this range three new lines have been added, i.e., the " Eclipse " No. 88 bit gauge, for attaching to an auger bit in a carpenter's brace, to facilitate the boring of holes to a pre-determined depth ; the " Eclipse " No. 79 saw set for circular saws, designed for setting the teeth of large circular saws up to a 10-gauge thickness ; and the " Eclipse " No. 12 metal pad handle, the design of which follows their No. 10 plastic pad handle. Other items on display in this section will include surface gauges, angle plates, tap wrenches, scribers, centre punches, and other tools.

The second section will feature magnetic devices, designed to accelerate production, the main display consisting of permanent-magnet chucks in both rectangular and circular models.

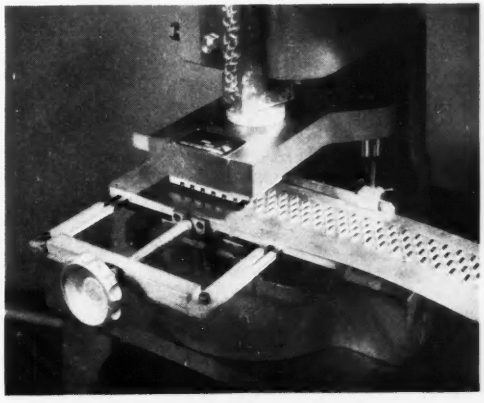
The exhibits of the **British Tyre & Rubber Co. Ltd.,** of London, S.W.1, will include, in addition to a comprehensive range of conveyor belting, elevator belts, hoses, flexible pipes, and V-belts, a selection of such items as industrial gloves and boots, rubber-covered rolls for various applications, marine craft rubber-lined bearings, and anti-corrosion tank and pipe linings.

In addition, " Pluvicor," the latest product of B.T.R. technical research, will be featured. This is a new fire-resistant compounded material, possessing great strength, wear resistance, and flexibility, and its development provides the coal-mining industry with a technically advanced fire-resistant multi-ply conveyor belting, which is durable, mildew inhibitive, waterproof, and immune to underground brine and acid waters.

Their new Mark III radiator core production equipment will be featured by **J. W. Lawrence Ltd.,** of Leicester. A standard Mark III installation comprises all the specialised machines and equipment necessary to manufacture tubular radiators up to 30 in. × 36 in. in size, at rates of up to a maximum of 50 average types per day.

The equipment, which is simple in design and which can readily be operated by any average mechanic, is of unit construction and fundamentally comprises a fin roller machine, a tube machine (in three stages, embodying a strip pre-tinning unit, a tube-forming machine, and an automatic tube cut-off), a header plate press, an assembly jig, and a soldering oven.

The illustration shows a close-up view of the header-plate press tool.



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M.-W. 347

Exhibits of **The Electric Construction Company Limited,** of Wolverhampton, will include one of a range of completely static full-float charging rectifiers, working on a demonstration G.P.O. exchange system.

In addition, one of a range of totally enclosed and pressure-ventilated electronically controlled Ward Leonard drives for application to machines where extremely rapid speed control and speed response are required, will be featured, together with a 15-kVA motor alternator set, including a self-excited, self-regulating alternator coupled to a totally enclosed squirrel-cage motor, built to the new British Standard Dimensions Specification No. 2083/1954. Two of the new range of British Standard Dimensions motors, one of which will be broken down to show its construction, will also be displayed.

Among the range of new tools which will be exhibited by **Moore & Wright (Sheffield) Ltd.,** of Sheffield, is a new micrometer, which features the latest form of ratchet built into the upper part of the thimble. It is designed for quick, easy, and accurate hand use; a knurled collar on the lower part of the thimble gives direct feel, if required.

Also exhibited will be their No. 899 small bore gauges, which are comparators used to measure accurately small holes, slots, and gaps. These gauges are different from the small-hole gauges at present available, inasmuch as they make measuring contact by means of hardened and spherically lapped balls, which give a definite " feel," with a complete absence of springing.

Other items to be displayed will include a combined pocket scriber and screwdriver, the R.D. type of spiral ratchet screwdriver, and additions to the Company's range of telescopic gauges, which now measure up to 13 in., the three additions having capacities of 5½ to 8 in., 8 in. to 10½ in., and 10½ to 13 in., respectively.

A range of sulpho-chlorinated cutting oils, one of which has been found particularly successful for broaching titanium alloys, will form part of the exhibits of **Manchester Oil Refinery (Sales) Ltd.,** of Manchester. Other cutting oils, suitable for use when machining high-tensile austenitic steels and the nimonic alloys, will also be shown, together with a full range of the Company's highly refined industrial oils and petroleum-derived chemicals.

Also of interest will be a range of petroleum-based flaw detection " inks," developed to reveal cracks and porosity in both magnetisable and non-magnetisable materials under ultraviolet light.

The range of products to be exhibited by **Parkinson & Cowan Industrial Products,** of London, E.C.1, will consist mainly of their gas-fired infra-red stoving and heating equipment.

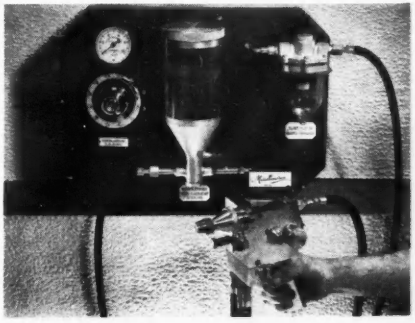
Featured will be an installation of two of their tunnel type units, 2 ft in diameter, making an oven of 6 ft in length, complete with overhead monorail conveyor, mounted directly on the units. A plant made up of panel units will also be shown; this consists of 24 panel units, each 36 in. in width × 18 in. in height, and the installation will provide an oven approximately 9 ft in length × 5 ft in height.

These two types of units are being widely used for paint stoving on sheet-metal components, and a range of typical examples will be exhibited as a cross-section of the varied type of components this plant can handle in production. Working models of wet-type laboratory gas meters, rotary check meters, and pressure gauges will also be included in the exhibit.

Prominent among the exhibits of **IOCO Limited,** of Glasgow, will be " Terapex " varnished insulating fabric. " Terapex " is based on terylene, developed by I.C.I. Ltd., the trade name for the resin polyethylene terephthalate. Terylene, which resembles nylon in appearance and certain properties, can be spun and woven into silk-like fabrics which possess some notable features from an electrical standpoint. These properties include high tensile and tearing strength; low moisture absorption; high resistance to solvent and chemical attack; and excellent dielectric properties.

The fabrics lend themselves to the varnishing process used in the manufacture of " Terapex." The varnishes used are synthetic, with excellent heat-resisting properties, and the coated fabric presents a smooth appearance with good flex resistance, capable of withstanding considerable mechanical usage.

Exhibitions and demonstrations of metal-spraying equipment will be given by **Metallisation Limited,** of Dudley. In addition, a new process of hard facing will be demonstrated. This is a combination of metal spraying and welding, the material being sprayed with a Mark 16 spraying pistol, using a special attachment, as illustrated.



A new lighting device for automatic metal-spraying machines, capable of lighting multi-nozzles with ease, will also be demonstrated.

A representative cross-section of their permanent-magnet and electromagnetic equipment will be exhibited by **Rapid Magnetic Machines Ltd.,** of Birmingham, and will include swarf separators, portable foundry separators, and electromagnetic ore separators.

A 20-in. diameter lifting magnet and a completely new self-cleaning magnet, known as the " Ejecta," will also be shown, together with a range of electric and non-electric self-cleaning drum and pulley type separators, and electromagnetic clutches and brakes for power transmission. A range of equipment for the collection of ferrous scrap from workshop floors will also be exhibited.

Electromagnetic chute-type separators will be shown, including the Company's type " V " separator, which is a vibratory machine designed to treat fine powders and other commodities of a similar consistency.

Fusegear, switchgear, motors, and instruments will be featured on the stand of **The English Electric Company Limited,** of London, W.C.2.

The display of fusegear will include a flush-type fuse switchboard; " Superform " distribution boards and isolators; an overhead busbar system; a display of cartridge fuses; substation equipment; and industrial fuseboards and combination fuse switchboards. Switchboard exhibits will include an F.600, 400 V, 25 MVA switchboard, incorporating a 1600 A, type OB.3, air circuit breaker and a 600 A, type OB. 2, air circuit breaker.

Five typical industrial motors will be shown, as follows :—A flange-mounted geared motor unit; a chemical-works motor; a foot-mounting LY motor; a crane motor; and a Buxton certified flame-proof motor. In addition, six typical fractional horse-power motors will be on view, as well as the " English Electric " hand drier and a selection of typical " English Electric " instruments.

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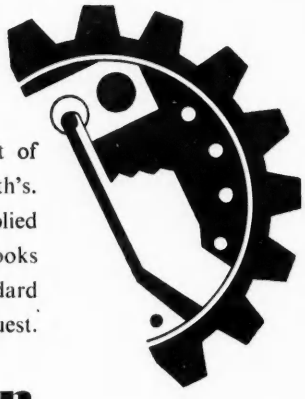

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NEWS OF THE MONTH

PERSONAL

Mr. **E. W. Bennett** has been appointed production manager, and **Mr. J. F. King** superintendent, P.E.D., of Hoover (Electric Motors) Limited, Cambuslang, Lanarkshire.

Mr. J. Blears has been appointed chief engineer, **Mr. R. S. Clark** assistant superintendent, **Mr. J. W. Buckley** sales manager, and **Mr. W. J. Brown** assistant sales manager, of the newly formed Scientific Apparatus Department of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17. The new department has been created by merging the vacuum-products activities of the Company with their new products department.

Mr. G. E. Carter has been appointed general sales manager of Tecalemit Ltd., Plymouth.

Mr. E. Y. Caswell has been appointed sales manager of the Skefko Ball Bearing Co. Ltd., Luton, Bedfordshire.

Mr. T. Christie has been appointed manager of the Neptune Shipyard of Swan, Hunter and Wigham Richardson Ltd., Walker-on-Tyne, in succession to **Mr. G. M. L. Logie,** who has retired after nearly 50 years service to the Company.

Dr. C. Dannatt, O.B.E., M.C., M.I.E.E., has been appointed deputy managing director of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17. **Mr. J. F. Perry, A.M.I.E.E.,** managing director of Metropolitan-Vickers Electrical Export Co., Ltd., has been appointed a director of the parent company. **Mr. Arthur C. Main, B.E., M.I.E.E.,** at present director and works manager, Trafford Park Works, has been appointed director of manufacture. **Mr. E. W. Steele, M.I.Mech.E., M.I.E.E.,** hitherto director and general manager of works, has retired from executive duties, but remains a director of the Company.

Mr. W. W. Downing, A.F.R.Ae.S., M.I.P.E., has been appointed works manager, **Mr. A. J. Pack** production manager, and **Mr. C. R. Bromage** assistant production manager, of the Gloster Aircraft Co. Ltd.

Dr. J. W. Drinkwater, O.B.E., has been appointed director of Engine Research and Development at the Ministry of Supply, in succession to **Mr. R. H. Weir,** who has recently been appointed principal director.

Mr. H. Dunn has been appointed sales manager for Scotland of Wellworthy Ltd., Lymington, Hants. His address remains at 50 Wellington Street, Glasgow, C.2.

Mr. H. W. Forshaw, O.B.E., M.Sc.Tech., M.I.E.E., has been appointed chief superintendent of the Signals Research and Development Establishment, Christchurch.

Mr. L. Gamsa, B.Sc., has been appointed sales manager of Slough Metals Ltd., Trading Estate, Slough.

Mr. J. D. Garst has been appointed director of operations of the Regent Oil Co. Ltd., 117 Park Street, London, W.1. **Mr. O. H. Fish** has been appointed assistant general sales manager of the Company.

Colonel J. D. Haigh, O.B.E., M.A., M.I.E.E., has been appointed director of Electronics Research and Development (Defence) at the Ministry of Supply.

Mr. G. A. Hannah, managing director of Pegson Ltd., Coalville, Leicestershire, has been elected to the Board of the parent company, Mellor, Bromley & Co. Ltd.

Mr. A. J. Harwood has been appointed chief engineer of Auto Transmission Ltd., Upper York Street, Coventry.

Mr. J. O. Hitchcock has relinquished his position as assistant managing director of Henry Wiggin & Co. Ltd., Wiggin Street, Birmingham 16, to assume, on May 1st, the position of assistant to the chairman of the Mond Nickel Co. Ltd. He remains a member of the Wiggin Board. **Mr. H. W. G. Hignett,** superintendent of the Mond Nickel Company's Development and Research Laboratory, has been appointed to the Wiggin Board and will take charge of technical (metallurgical) control and development in all the Wiggin plants. He is succeeded as superintendent of the Laboratory by **Mr. H. Evans. Mr. R. E. Ansell,** manager of the sales department, has been elected to the Wiggin Board. **Mr. O. Lewis Jones** has been appointed general production manager, responsible for production in all the Wiggin plants. He is succeeded as works manager at Birmingham by **Mr. C. E. Winfield. Mr. A. B. Graham,** general manager of the Zenith Works at Glasgow, will relinquish this position on July 1st, but will undertake special duties in connection with production. **Mr. R. J. P. Macdonald** has been appointed works manager of the Zenith Works.

Mr. P. M. Hollingsworth, M.Eng.(Liverpool), M.I.E.E., has been appointed chief engineer of the power cables division of British Insulated Callender's Cables Ltd., at 21 Bloomsbury Street, London, W.C.1, to succeed **Mr. W. P. Fuller** on his eventual retirement.

Mr. S. E. Holmes has been appointed manager, and **Mr. H. M. White** assistant manager, of the Department for Technical Information of C. C. Wakefield & Company Ltd., London, W.1.

Mr. A. W. Montgomery, joint general manager of Standard Telephones and Cables Ltd., Connaught House, Aldwych, London, has been elected a Fellow of the American Institute of Radio Engineers.

H. D. Parsons has relinquished his position as associate director of Enfield Cables Ltd., to take up appointment as general sales manager with W. T. Henley's Telegraph Works Co. Ltd., 95 Aldwych, London, W.C.2.

Mr. A. G. Peacock has resigned his position as secretary of the Scientific Instrument Manufacturers' Association and has joined the Board of Mervyn Instruments Ltd., St. John's, Woking, Surrey.

Mr. V. R. Prehn, works director of Ruston & Hornsby Ltd., Lincoln, has been appointed assistant managing director of the Company. **Mr. G. B. R. Fielden,** chief engineer, gas turbines, has been appointed engineering director.

Mr. G. W. Rose, O.B.E., T.D., A.M.I.Mech.E., has been appointed works manager of the car division of the Austin Motor Co. Ltd., Longbridge, Birmingham.

Mr. George Rushton, sales manager of the Roller-Bearing Division of Geo. Salter & Co. Ltd., West Bromwich, has been appointed, in addition, sales manager of the Company's Retaining-Ring Division.

Mr. S. S. Seabrook has joined the Dowty Group of Companies, Arle Court, Cheltenham, as publicity manager.

Mr. A. E. Skan, a director of George Ellison Ltd., Perry Barr, Birmingham, has been elected chairman of the British Plastics Federation.

Mr. R. W. Taylor, C.M.G., B.Sc.(Eng.), A.M.I.C.E., director of public works in Kenya, has been appointed engineer-in-chief, Crown Agents for the Colonies, 4 Millbank, London, S.W.1, in succession to **Mr. R. W. Foxlee, C.M.G., C.B.E., M.I.C.E.,** who is shortly to retire.

Mr. W. H. Taylor, B.Sc., A.M.I.E.E., has taken up his new duties as controller of Education and Personnel Services to The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2.

Mr. H. P. White, B.Sc., has been appointed head of the data and publications section of the Technical Service Department (T.S.D.) of Mullard Ltd., Century House, Shaftesbury Avenue, London, W.C.1, in succession to **Mr. Harley Carter,** who will, in future, devote his entire time to the Mullard Educational Service.

Mr. J. D. Whitell, F.S.S., F.R.Econ.S., has been appointed publicity manager to the B.S.A. Tools Group of Companies.

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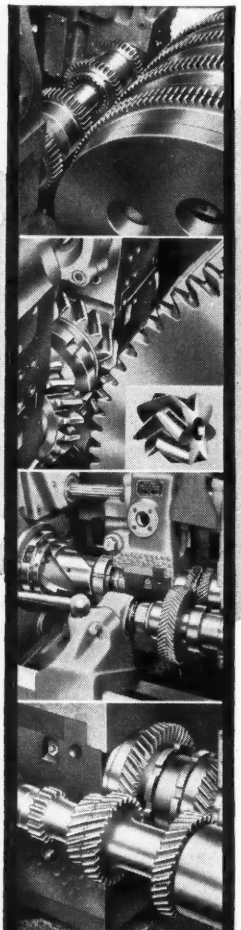
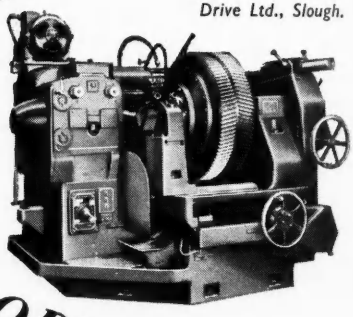


FLEXIBILITY IN GEAR PRODUCTION

No. 3C Machine at the Works of Modern Wheel Drive Ltd., Slough.



SYKES MULTI-CUTTER HORIZONTAL GEAR GENERATORS

Easy to set up — fully automatic in action — these machines have a wide range of applications. Externals and internals ; spurs, helicals, and splines can all be generated at high production rates, yet with the utmost precision. The multi-cutter principle, besides permitting up to 12 or more externals to be generated at once, also allows simultaneous cutting of both helices of continuous or staggered tooth double helicals. With a cluster gear attachment, gears differing in number of teeth or helix angle can be generated in one operation.

3 MODELS

1A up to 12 in. dia. by 5 in. face
3C up to 40 in. dia. by 10 in. face
5E (non-automatic) up to 66 in. dia. by 18 in. face.

Full technical data on request. You are cordially invited to inspect these machines at our works.

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BUSINESS NOTES

Brook Motors Limited, of Huddersfield, announce the removal to larger premises at 35 Pink Lane, of their Newcastle-upon-Tyne Sales Office; telephone number, Newcastle 26763. The Company has recently taken over another factory at Apsley, Huddersfield; an additional floor space of nearly 20,000 sq ft will thus be made available and will be used for the manufacture of electrical stampings. The official opening of their Barnsley factory has been fixed for May 28, 1954.

The sole agency in Great Britain for **Wanderer,** manufacturers of plain and universal milling machines, thread-milling, and hobbing machines, has changed to **Stanley Howard Limited,** 75-76 Exchange Buildings, Stephenson Place, Birmingham 2.

In commemoration of 75 years of service to industry, **Thos. W. Ward Limited,** Albion Works, Sheffield, have published a book, entitled "Outline of Progress," reviewing the field of activities covered by every department of the company and its subsidiary and associated companies. This 212-page publication, a limited edition of which has been distributed, is superbly conceived, produced, and illustrated.

THE INSTITUTE OF METALS

The 1954 Spring Meeting of the Institute of Metals will be held in London from April 26 to May 1, jointly with the Société Française de Métallurgie, with an extension from May 2 to May 4, for members and ladies of the French Society. This is the first occasion on which the Institute of Metals (or, so far as is known, any British metallurgical society) has acted as host in the United Kingdom to a foreign metallurgical society.

Members of the Iron and Steel Institute are being invited to attend the meeting on the same basis as those of the Institute of Metals and, as the Société Française de Métallurgie covers both ferrous and non-ferrous metallurgy, a session on ferrous metallurgy is being arranged in co-operation with the Iron and Steel Institute, whose President is Patron.

The programme arranged for the meeting should prove of interest to members engaged in widely differing fields of work. With the exception of the May Lecture, all scientific sessions will be held at Church House, Great Smith Street, Westminster, London, S.W.1.

THE INSTITUTE OF WELDING

The Spring Meeting of the Institute of Welding is being held this year from April 28 to May 1 in South Wales and Bristol. It will open on the evening of April 28 at Porthcawl, Glamorganshire; lectures and a works visit are being organised in South Wales on April 29, and on the evening of that day members will proceed to Bristol, where the meeting will continue on April 30 and the morning of May 1. The South Wales and South Western Branches are co-operating in the organisation of the meeting.

The following papers will be presented:—"Steelmaking and Welding," by Dr. L. Reeve, B.Sc.; "Hydrogen—Barrier to Welding Progress," by Dr. C. L. M. Cottrell, M.Sc.; "Nitrogen-Arc Welding of Copper," by E. Davis, M.Sc., F.I.M., and C. A. Terry, B.Sc.; "Nitrogen-Arc Welding of Copper," by Dr. K. Winterton, B.Sc., A.I.M.; "Welding in the Aero Engine Industry—Reflections on Organisation by a Production Engineer," by F. G. C. Sandiford, A.M.I.Mech.E., A.F.R.Aer.S., M.I.Prod.E.; and "Welding as a Career," by F. Koenigsberger, Dipl.Ing., M.I.Mech.E.

FOURTH GAUGE AND TOOL EXHIBITION

The Fourth Gauge and Tool Exhibition will be held this year from May 17 to May 28, 1954, at the New Horticultural Hall, Westminster, London, S.W.1.

A brochure in English, French, and German, setting out the general arrangements of the exhibition, has been printed and is being circulated by the Gauge and Tool Makers' Association on a wide scale throughout Great Britain and overseas.

AMERICAN SOCIETY FOR QUALITY CONTROL

The Eighth Annual Convention of the American Society for Quality Control will be held in St. Louis, Missouri, from June 9 to June 11, 1954. The Jefferson Hotel will be the headquarters for this convention, while the technical sessions will be held at Kiel Auditorium.

The programme will consist of 72 sessions, which will include 67 technical sessions and 5 sessions devoted to plant tours. Participants include the chemical and textile divisions, the aircraft, automotive, electronics, metals, and operations research committees, the business operation committee, and the basic research committee.

Registration blanks and further information may be obtained from:—MR. U. C. GRAMSCH, Registrar; 8th Annual A.S.Q.C. Convention; P.O. Box 4436, Wade Station; St. Louis 15, Missouri.

BRITISH-MADE DIES FOR PRODUCTION OF U.S. CARS

Many of the cars made in America next year will have bodies produced in part from British-made dies and fixtures, as Vauxhall Motors Ltd. have just completed the manufacture of dies and associated equipment to the value of 600,000 dollars for the Fisher Body Division of General Motors Corporation, which makes bodies for Chevrolet, Pontiac, Oldsmobile, Buick, and Cadillac cars.

Fisher Body normally place a proportion of their press-tool work with American jobbing firms. Similarly, Vauxhall's die-making facilities are normally fully employed in producing dies for their own models. In between model changes, however, some surplus capacity is available, and at these times Vauxhall have done work for many other companies. This is the first time, however, that Vauxhall have made dies for use in America.

The contract covers 110 separate items, including dies (some of them weighing 26 tons), press-welding fixtures, and projection-welding set-ups, together with checking fixtures, wood models, and master construction models. Work began on the contract last August, and the last item will be shipped this month.

SWITCHGEAR AT NECHELLS "B" POWER STATION.

The new Nechells "B" Generating Station of the British Electricity Authority, now approaching completion on a site adjacent to the original "A" Station in Birmingham, is equipped with four air-cooled turbo-alternators with a total capacity of 260 MVA. The General Electric Co. Ltd., which supplied much of the electrical plant and equipment for the old station, has supplied the whole of the 11 kV main and group switchgear for the "B" station, as well as the remote control switchboards and desks for the complete control of both stations, metering panels, and the busbar protection equipment.

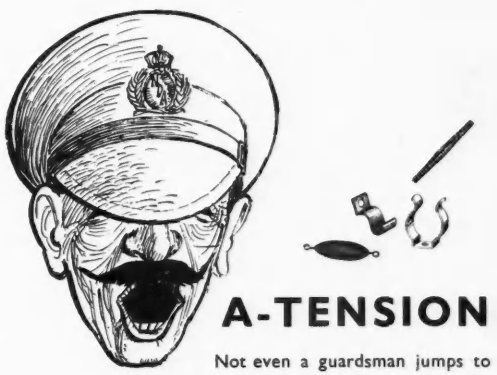
The 11-kV switchgear is of particular interest, as it represents an unusual combination of new and old equipment. For generators 3 and 4, the main and group switchgear is of the G.E.C. metalclad type and incorporates all the latest refinements of modern switchgear design. In the case of generators 1 and 2, corresponding gear is the original stonework cubicle type supplied to the "A" station over 27 years ago. After this long period of service, the switchgear has been modernised, to make it suitable for the same duty as its modern counterpart.

ELECTRIC-RAILWAY CONTRACT FOR BRAZIL

One of the largest contracts for electric-railway equipment ever placed has been awarded to Metropolitan-Vickers. The Central Railway of Brazil has ordered two hundred complete railway coaches, to be built and equipped in Great Britain, and a hundred sets of electrical equipment for fitting to coaches of Brazilian construction. These will provide one hundred new three-coach trains for Rio de Janeiro suburban lines.

This contract, which is financed in part by an International Bank loan of 12,500,000 dollars and is worth about £7,000,000, was obtained for Britain in the face of severe foreign competition, bids being put in from the United States, France, Belgium, Holland, Germany, Switzerland, and Japan, as well as from Brazil herself.

The electrical equipment involved will be made at the Metropolitan-Vickers factories at Sheffield and Trafford Park, Manchester, and the coaches will be constructed at the Metropolitan-Cammell Works at Saltley, near Birmingham. Each coach is 22



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We've spent over thirty years making them and every one has been designed to do a specific job as well as it could possibly be done. It's becoming a habit for progressive engineers to call us in at the design stage.

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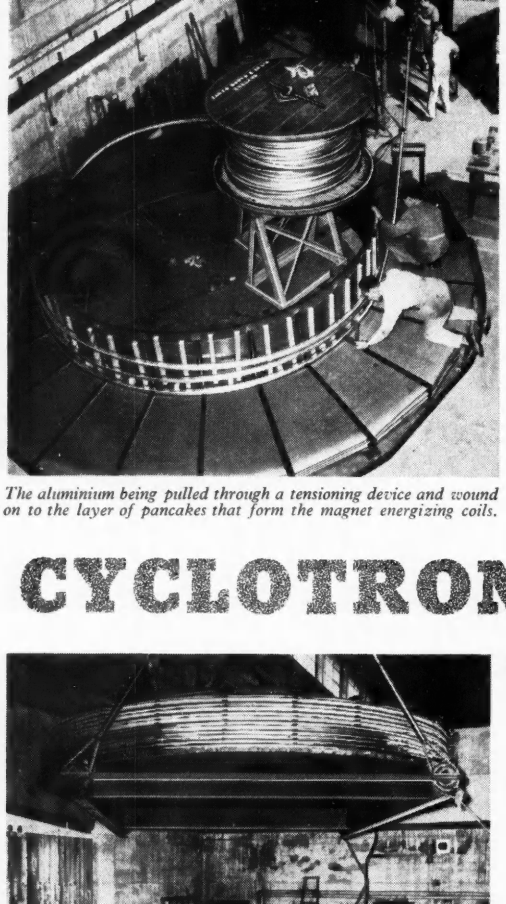
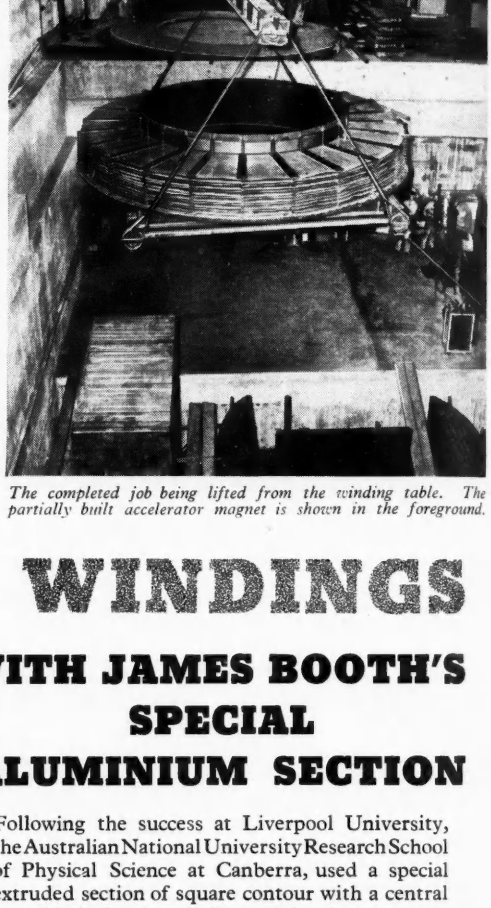
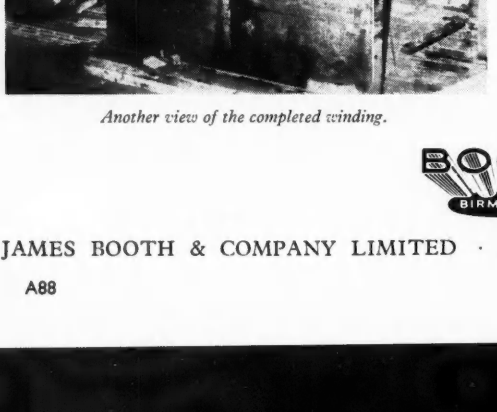


The aluminium being pulled through a tensioning device and wound on to the layer of pancakes that form the magnet energizing coils.



The completed job being lifted from the winding table. The partially built accelerator magnet is shown in the foreground.

CYCLOTRON WINDINGS



Another view of the completed winding.

WITH JAMES BOOTH'S SPECIAL ALUMINIUM SECTION

Following the success at Liverpool University, the Australian National University Research School of Physical Science at Canberra, used a special extruded section of square contour with a central round hole for the windings of the electromagnet of the cyclotron recently constructed in Australia. This meant a demand for 16 continuous lengths of section each 2,300 ft. long, and the successful production of faultless lengths of such extent represents no small metallurgical achievement. If, however, the versatility of aluminium and the flexibility of the extrusion process is used in conjunction with the art and perseverance of our skilled technicians, the most ambitious aspirations of the drawing board can often be brought to reality.

If your problem is unusual—so also will be our endeavours to help you if you care to consult us, without obligation, of course.

Photographs — reproduced by courtesy of the University — show the job in progress.

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metres in length, and each motor coach is equipped with four traction motors, giving a total of 1,280 hp per motor coach. Control is electro-pneumatic, and the maximum speed of the new trains is 53 mph. They are of somewhat greater power than the existing rolling stock, but old and new coaches will be used together in multiple units, thus enabling the service to be speeded up.

BUTIADENE-BASED PLASTIC MATERIAL

Imperial Chemical Industries Ltd. have plans for the first large-scale production in Great Britain of a range of rubber-like polymers based on butadiene. Pilot-plant quantities should be available later this year, but it is not expected that the full-scale plant at Wilton, North Yorkshire, which will have a planned capacity of about 10,000 tons per year, will commence operation before 1956.

Using butadiene produced in I.C.I.'s oil cracker at Wilton, it is intended to manufacture copolymers using a variety of second components, including acrylonitrile and styrene. These copolymers will cover a range from oil-resisting substances of the Perbunan type to hard, reinforcing resins. Some of the polymers it is proposed to manufacture will be similar to those already being made in the United States, but others will be novel, both in composition and in properties. They will all be speciality materials, designed to provide effects which at the present time can be achieved only by restricted imports from the United States.

I.C.I.'s Plastics Division, with headquarters at Welwyn Garden City, will be responsible for polymer production, development, and sales, using raw materials obtained mostly from other Divisions of the company.

DIESEL-ELECTRIC LOCOMOTIVES FOR BRAZIL

The English Electric Company is supplying thirteen 1000-hp diesel-electric locomotives for passenger and freight service on the metre-gauge system of the Rede Ferroviara do Nordeste, Brazil. The diesel-electric power equipment is being built by The English Electric Company and the mechanical parts by the Vulcan Foundry.

The locomotives are of the A1A-A1A type, having two three-axle bogies, the outer axles of which are motored. Up to three locomotives may be coupled together and driven in multiple from one cab, and, to protect the locomotive against improper use and to warn the driver of incorrect operation of the equipment, no less than five protective devices are fitted.

WATERWHEEL GENERATORS

Metropolitan-Vickers Electrical Export Co., Ltd. has received an order from the Quebec Hydro-Electric Commission for four 138,000-kW waterwheel generators. The value of this contract, which was obtained in the face of international competition, approaches 3,000,000 dollars. These generators, which will be the most powerful of their kind in the world, will be manufactured at the Trafford Park Works of Metropolitan-Vickers Electrical Co., Ltd., and the first two are to be commissioned by the end of 1956. They will be installed at the Lac Casse Development on the Bersimis River, where a new power station is to be constructed, principally for supplying power to Quebec and Montreal.

Each generator is rated at 120,000 kVA for normal service and 138,000 kVA for maximum continuous service. both ratings being at any power factor from 0·95 to unity. The speed is 277 rpm, and the voltage is 13·8 kV at 60 cps. The generators are vertical-shaft machines, driven by Francis-type turbines, and employ a special type of spring-supported thrust bearing. Each generator will be controlled on the Metropolitan-Vickers ultra-rapid voltage regulating system.

BRITISH STANDARDS

Dimensions of 3-phase Electric Motors. B.S. 2083 : 1954 establishes nine frame sizes for squirrel-cage, totally enclosed fan-cooled foot-mounted motors intended for industrial purposes and having a maximum continuous rating; it is applicable to 50-cycle motors at voltages not greater than 650 volts and covers motors of 1-20 horse-power at 1500 rpm (synchronous speed).

With the exception of the 1-hp 4-pole motor, the dimensions specified are similar to those given in the American NEMA Standard MG 1-1949, but for a given frame size the horse-power outputs have been increased to fall into line with practice in this country, and shaft dimensions have been enlarged accordingly. Price 2/6.

Copper Alloy Globe Valves for General Purposes. B.S. 2060 : 1953 specifies requirements for rating, design and manufacture, materials, dimensions, tests, and marking for copper-alloy globe, angle, and oblique (or "Y") valves with rising stem, inside or outside screw, with flanged or screwed ends, of Classes 100, 125, 150, 200 and 250, for a range of nominal sizes from ¼ in. to 3 in. Price 4/-.

Dimensions of Diamond Abrasive Wheels and Tools. B.S. 2064 : 1953 specifies dimensions and tolerances of the following tools in resinoid, vitrified, and metallic bonds :—

Peripheral wheels, straight cup wheels, double cup wheels, taper cup wheels, bull-nosed cup wheels, dish wheels, cut-off wheels, chip-breaker wheels, milling tools, hollow drills, stone saws, and hones. Price 4/-.

Chains & Wheels for Single Bottle Width Slat Conveyors. B.S. 2075 : 1954 has been prepared under the authority of the Dairying Industry Standards Committee, the Food Machinery Association, and the Mineral Water Engineers Association. It is hoped that it will prove of advantage to all industries which use this type of conveyor for transporting bottles of about the same size as milk bottles.

Owing to the fact that the adoption of a standard form of integral-slat conveyor would necessitate some modification to all existing designs, the Committee decided to confine this British Standard to the roller chain and slat band chain types of conveyors.

The specification details the materials and dimensions of both the chains and the slats, together with tolerances. Price 2/6.

Ferrous Pipes and Piping Installations for and in Connection with Land Boilers. B.S. 806 : 1954 applies to the design and construction of the ferrous pipework connecting a land steam boiler to engine, turbine, or industrial plant and all auxiliary pipework in connection therewith, together with the pipes and pipe fittings forming parts of such installations for :

(a) pipes of any bore, where the pressure exceeds 50 lb/sq. in.
(b) pipes over 10 in. bore for steam at pressures up to and including 50 lb/sq. in.

This standard does not apply to the use of carbon steel where the temperature exceeds 900° F., or to the use of alloy steel where the temperature exceeds 975° F.

The scope of this Standard has been extended to provide for developments which have taken place in pipework installation practice, notably in the use of alloy steels.

Material specifications are included for :

Class A.	Cold-drawn seamless carbon steel pipes.
Class B & C.	Hot-finished seamless carbon steel pipes.
Class D.	Hydraulic lap-welded carbon steel pipes.
Class E.	Roll lap-welded carbon steel pipes.
Class F.	Butt-welded carbon steel pipes.
Class M.	Cold-drawn seamless molybdenum steel pipes.
Class P.	Cold-drawn seamless chromium molybdenum steel pipes.
Class Q.	Hot-finished seamless chromium molybdenum steel pipes.

Sections deal with :

(i) Design requirements.
(ii) Procedure to be observed in the manipulation and fabrication of alloy-steel pipes.
(iii) Construction, including the attachment of flanges.

This Standard also contains Appendices covering *inter alia* :

(i) Young's modulus for steel pipes.
(ii) Percentage elongation on various gauge lengths.
(iii) Diameters and thicknesses of steel pipes applicable to this Standard.
(iv) Pressures in safety-valve discharge piping.
(v) Examples of reinforcement of multiple branches. Price 10/6

Dial Gauges for Linear Measurements. B.S. 907 : 1954. Dial gauges are among the most widely used of engineers' precision tools and many developments in design have taken place since B.S. 907 was first published in 1940. The present revision takes

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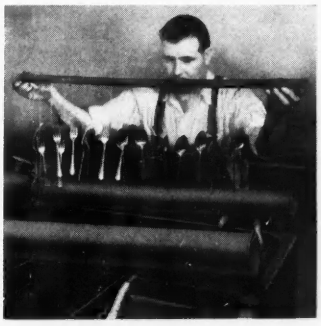

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Whatever your process BENETSOL "E" will raise efficiency and lower costs. BENETSOL "E" actually costs less than 1½d. per gallon for standard mixing.

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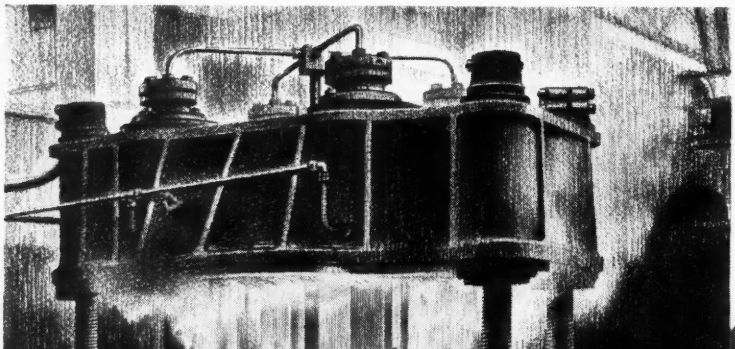
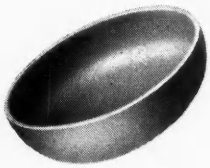
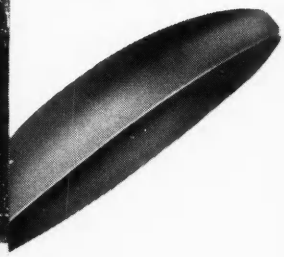
Write to Manufacturers for further details and sample.

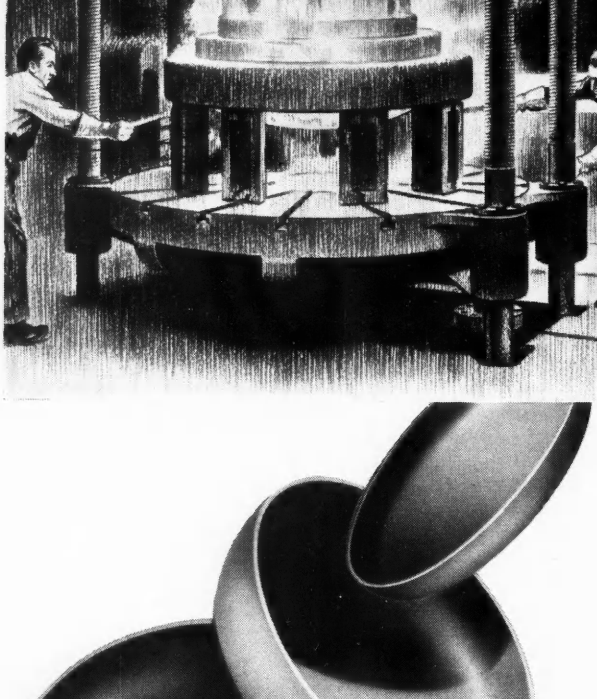
Manufactured by BENNETT (HYDE) LTD., BOSTON MILLS, HYDE, CHESHIRE.







DISHED and FLANGED ENDS



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account of this in specifying standards of performance and incorporates a number of modifications which experience of working to the previous standard has shown to be desirable. It also makes provision for the back plunger type of dial guage now in very general use.

In English measure, two types of dial graduations are provided for: Those divided into units of 0·001 in. (sometimes sub-divided into half units of 0·0005 in.) and known as one-thousandth inch gauges, and those divided into units of 0·0001 in. and known as one-ten-thousandth inch gauges.

In metric measure, the standard is confined to dials graduated in units of 0·01 mm.

Recommended dimensions, methods of testing, and notes on the care and use of dial gauges are given in appendices. Price 3/-.

BOOKS RECEIVED

Workshop Costs and Costing. By P. S. Houghton, A.M.I.Mech.E. 307 pp., 50 illustrations. Publishers: Chapman & Hall Limited, 37 Essex Street, London, W.C.2. Price: 35/-.

This book on workshop costing is written by an engineer who, whilst holding managerial posts in a number of manufacturing concerns, has on several occasions been forced to create some means whereby a good measure of control could be obtained over both labour and material costs, in direct expenses and production. This book is, therefore, based on practical experience of the needs and point of view of the engineering workshop, and should prove of great value to all connected with workshop management.

Cost control is essential to-day, and the book explains how a costing system can be installed and efficiently maintained. Included are details of price variation, costing systems and terms, indirect expenses, normal expenses, wage systems, the checking of waste, the creation of a costing system, foundry costing, stock accounts, financial and cost accounts reconciliation, and contract and process costing.

Gears. Third edition, 1954. By H. E. Merritt, M.B.E., D.Sc. (Eng.) Lond., M.I.Mech.E. 540 pp., 253 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 60/-.

This new edition has been rearranged and very largely rewritten, and incorporates new material and new treatments. For example, separate chapters are now devoted both to the geometry and to the detail dimensions of gears, while a new chapter on some special types of gears has been added.

The changes and additions are too numerous to describe in detail, but reference may be made to the question of rating formulae. Further study has shown that the rating methods (with which the author was originally associated), given in earlier editions and in the relevant British Standards, can be re-expressed in a way which leads to a more rational connection between the inevitable assumptions. This restatement is accompanied by a full range of recalculated charts.

This authoritative and well-illustrated book is of undoubted value to all concerned with the design and manufacture of gears.

Electrical Engineering for Mining Students. Second edition, 1954. By G. M. Harvey, M.Sc., B.Eng., M.I.E.E. 166 pp., 114 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 15/-.

Many developments in the application of electricity to mining have taken place since this book was first issued. In this edition, the text has been revised and brought into line with modern practice. It gives an elementary outline, with a minimum of mathematics, of basic electrical theory, and describes the principles of operation of the electrical machinery in common use in coal and metal mining.

Students of mining engineering should find the information contained in this handy little volume of great value.

Electronics. By A. T. Starr, M.A., Ph.D., M.I.E.E. 403 pp., 352 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 32/6.

The subject of Telecommunications in the London University Degree has recently been divided into Telecommunications and Electronics. This book has been specially written to cover the syllabus for Electronics, which is roughly that of light-current engineering, in which there is a certain emphasis outside Telecommunications.

This book, which is the latest addition to the well-known "Engineering Degree Series," should prove useful at other universities as well, and to students taking professional examinations, such as those of the I.E.E. and the British Institution of Radio Engineers.

The physical and mathematical aspects of electronics have been stressed, and there are appendices on a.c. theory, Fourier analysis, operational calculus, etc. These should be valuable in supplementing the mathematical equipment of the student. In addition, a representative selection of questions, many from recent examinations, is included.

New Methods for Sheet Metal Work. Fourth edition, 1954. By W. Cookson, M.Inst.Met., M.I.Prod.E. 219 pp., 87 illustrations. Publishers: The Technical Press Ltd., 1 Justice Walk, Lawrence Street, London, S.W.3. Price: 16/-.

Sheet-metal working nowadays is taking its place in many industries as a craft which requires a high standard of technical efficiency. In particular, it is gradually being recognised that the art of marking-out templates used in the fabrication of many classes of sheet-metal goods calls for a sound training in workshop mathematics and the ability to understand the principles of practical pattern development.

The main objects of this book are to cater for the sheet-metal engineer by modernising and simplifying geometrical development procedure, and to put the practice of laying-out patterns on a more exact basis than has hitherto been deemed possible. In this connection, the chapters dealing with the development of sheet-metal patterns by mathematical formulae, particularly as applied to triangulation problems, are the first of their kind to be published.

In this new edition, two chapters, dealing with irregular surface perimeter calculations, have been included.

Gears for Small Mechanisms. By W. O. Davis. 167 pp., 88 illustrations. Publishers: N. A. G. Press Ltd., 226 Latymer Court, Hammersmith, London, W.6. Price: 25/- (postage 1/-).

Although involute gears have exceptionally wide applications in power engineering, they are not successful on a small scale. The reason for this is given by Mr. Davis in his book, in which a thorough analysis is made for the first time of gears for small mechanisms.

Lantern pinions used in some clocks to-day are direct descendants of the large gears used more than a century ago in windmills for driving grindstones. Strange as it may seem at first sight, the problems of the old-time millwright have a close resemblance to those of the modern watchmaker, because the relative precision of their work is similar. The manufacturing tolerances of crude mill gears of six feet in diameter were in the same proportion as those of tiny watch wheels, and the justification for their shapes is much the same.

Written by an engineer who has specialised in small gears and pecial mechanisms for twenty years, this book offers invaluable advice to designers, producers, and users of small mechanisms, and should be even more welcome, inasmuch as the information it gives is not available elsewhere.

Applied Thermodynamics. Third edition, 1954. By William Robinson, M.E., revised by John M. Dickson, B.Sc. 680 pp., 253 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 40/-.

This standard textbook, the aim of which is to aid engineering students and engineers studying heat engines and the scientific principles which condition their performance and thermal efficiency, covers the syllabuses of the B.Sc.(Eng.), Inst.C.E., and I.Mech.E. examinations in this subject.

This new edition has been revised and has been brought up to date, and includes an entirely new chapter on the First Principles of Heat Transmission. The simple treatment of this book, which is one in the Engineering Degree Series, makes it invaluable as a text-book, while the numerous sketches, diagrams, etc., will be found especially useful. Examination questions, taken from papers set by the University of London and the Institutions of Civil and Mechanical Engineers, add still further value to a book which should be in the hands of all who are studying heat engines.

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Textbook of the Materials of Engineering. Eighth editio.., 1953. By Herbert F. Moore and Mark B. Moore. 381 pp., 140 illustrations. Publishers: McGraw-Hill Publishing Company Ltd., 95 Farringdon Street, London, E.C.4. Price: 48/-.

Whenever a structural or a machine part is to be designed, it is necessary to consider various factors, among which the three most important are concerned with the forces and moments the part is required to withstand; the form and dimensions of the part, to ensure it will function properly without failure; and the best material to use, considering resistance to fracture, collapse, or change of form. The first two of these factors are more or less interdependent, and the methods and formulae of applied mechanics may be used in their study, provided the limitations of such formulae are recognised. This book concerns itself mainly with the third factor—the properties of structural materials which enable them to offer successful resistance to structural damage by applied moments and forces.

The eighth edition of this well-known work has been written by Herbert F. Moore, Research Professor of Engineering Materials, Emeritus, University of Illinois, and Mark B. Moore, Associate Professor of Mechanical Engineering, Rutgers University. In this edition, the chapter on "Cohesion, Stress, and Strain" was written by J. O. Draffin, Professor of Theoretical and Applied Mechanics, University of Illinois; the chapter on "Concrete" was revised by H. F. Gonnerman, Assistant to the Vice-President for Research, Portland Cement Association, Chicago, while the chapter on "Plastics" was revised by W. N. Findley, Associate Professor in charge of the Plastics Laboratory, University of Illinois.

The authors have tried to meet the problem of discussing the properties of the more promising of the newer materials without making too long a book, by cutting down the discussion of properties of materials not closely connected with the resistance of materials to applied loads and moments, and by omitting the list of visual aids printed in the seventh edition.

Altogether, this is an excellent book of its kind, well conceived and illustrated.

Solution of Problems in Engineering Drawing and Projective Geometry. By K. L. Jackson, M.Sc.(Eng.), A.M.I.Mech.E., A.M.I.P.E. 60 pp., 40 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker House, Kingsway, London, W.C.2. Price: 10/-.

This book contains a selection of problems in engineering drawing and projective geometry, specially chosen from examination papers of the University of London, for the use of students preparing for the B.Sc.(Eng.) degree, or taking National Certificate courses.

The book has been divided into two parts, *viz.*: Engineering Drawing and Projective Geometry, respectively; at the end of each part, model solutions are given for each question, thereby enabling the student to check his work. In the case of the geometric problems, a key construction is shown, and the sequence of operations is numbered, where necessary.

This is a book which should be of value both in the drawing office and for use in home study.

Kempe's Engineer's Year-Book, 1954. 59th Edition. Edited by C. R. Prockter, M.I.E.E., M.I.Mech.E., under the direction of B. W. Pendred, M.I.Mech.E., M.I.S.I. Two Volumes, 2810 pp., approx. 1500 illustrations. Publishers: Morgan Brothers (Publishers) Ltd., 28 Essex Street, Strand, London, W.C.2. Price (two volumes in case): 75/- (Postage 2/6).

The 1954 Edition of this well-known reference book has been entirely rewritten and has been reset in a clearer typeface. The total number of chapters is now 79, as against 70 in earlier editions, of which eight chapters are entirely new, *viz.*:—Atomic Power; Explosives; Electric Engineering Fundamentals; Industrial Safety; Mechanical Handling; Plastics; Powder Metallurgy; and Theory of Structures.

Every chapter, with the exception of that on gearing, has received major revision and has been brought up to date. A vast amount of additional material has been introduced, so that many of the existing chapters are virtually new. Thus, for example, so much new material has been incorporated in Metallurgy that it has been subdivided into "Iron and Steel," "Non-Ferrous Metals," and "Foundry Practice." In other fields, however, repetition has been avoided by bringing together chapters which were originally separate. For instance, "Marine Oil Engines" and "Marine Steam Engines" are now combined in "Marine Engines," while "Heating" and "Ventilation" are combined under "Heating, Ventilation and Air Conditioning." The index has been considerably enlarged and now contains 17,000 references, as against 12,000 in earlier editions.

This latest edition of "Kempe's" should prove of great use to all engineers, covering as it does a very wide range of subjects concisely and authoritatively.

The Manufacture and Properties of Steel Wire. By Anton Pomp, Dr.-Ing. 358 pp., 404 illustrations. Publishers: The Wire Industry Ltd., 33 Furnival Street, London, E.C.4. Price: 84/-.

This volume, the first on the subject published in Great Britain since the war, is a translation by C. P. Bernhoeft of the second revised edition of "Stahldraht," by Dr. Anton Pomp, an acknowledged Continental authority on the subject of wire drawing.

The book is subdivided according to the various processes involved in wire drawing, and for each process the author discusses both theoretical considerations and the effect of the operations carried out, before turning to a full description of the practical methods in use in the industry on the Continent, in Great Britain, and in America.

After a general survey of the historical development of steel-wire production, the author describes the raw material and discusses, amongst other things, dimensions, the manufacturing process, chemical composition, etc. This is followed by a chapter on the finished product and includes reference to physical properties, shapes, surface condition, tolerances, gauges, and measuring instruments. The various methods of pickling and descaling, and their advantages and disadvantages, are dealt with fully, as are also the installations required for carrying out this process, and the subsequent treatment of pickled wire.

Various sections are devoted to the fundamentals of wire drawing and alterations in the properties of the material through drawing, while the different types of wire-drawing machines, coilers, spoolers, welders, and drawing dies are fully described and illustrated. Comparisons are also given of the various types of lubricants available. Other chapters deal with such subjects as annealing, patenting, hardening, tempering, galvanising, tinning, testing of coatings, straightening and cutting off, grinding and polishing, production of flat wire, wire testing, etc.

This book covers the subject very thoroughly and should be of great practical value to all concerned in the manufacture of steel wire.

Electrical Trades Directory 1954. 72nd Edition. 1540 pages. Publishers: Benn Brothers Limited, Bouverie House, 154 Fleet Street, London, E.C.4. Price: 50/-.

Containing well over 61,000 references, the 72nd edition of this well-known Directory retains all the features completed last year, and includes notable additions in most of the sections covering the whole structure of the electrical industry. The list of manufacturers has been extended to nearly 7000, while increases are also evident in the number of electrical engineers, installation contractors, wholesalers, and distributors.

Developments planned to meet requirements of industry and also of the technical branches of the Services have necessitated the introduction in the Products and Materials Section of a number of headings descriptive of new equipment, components, and materials. This Section, with some 40,000 references, is the largest in the Directory.

A useful feature is the Trade Names Section, in which are listed the registered names of nearly 5000 patented products. Valuable information is also provided relating to the British Electricity Authority, Government research establishments, British Railways and London Transport, the Institution of Electrical Engineers, etc.

In short, this ever-expanding source of information is indispensable to all who require a reliable and completely up-to-date guide to the electrical and allied industries and trades.

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WANTED.—Copies of the March, 1953 issue of "The Engineers' Digest" urgently required. Also Jan., 1949, June, 1950, and Dec., 1951, issues at 3/6 per copy.—Subscription Dept., 120, Wigmore Street, London, W.1.

THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *SELECTION OF BRITTLE MATERIALS*

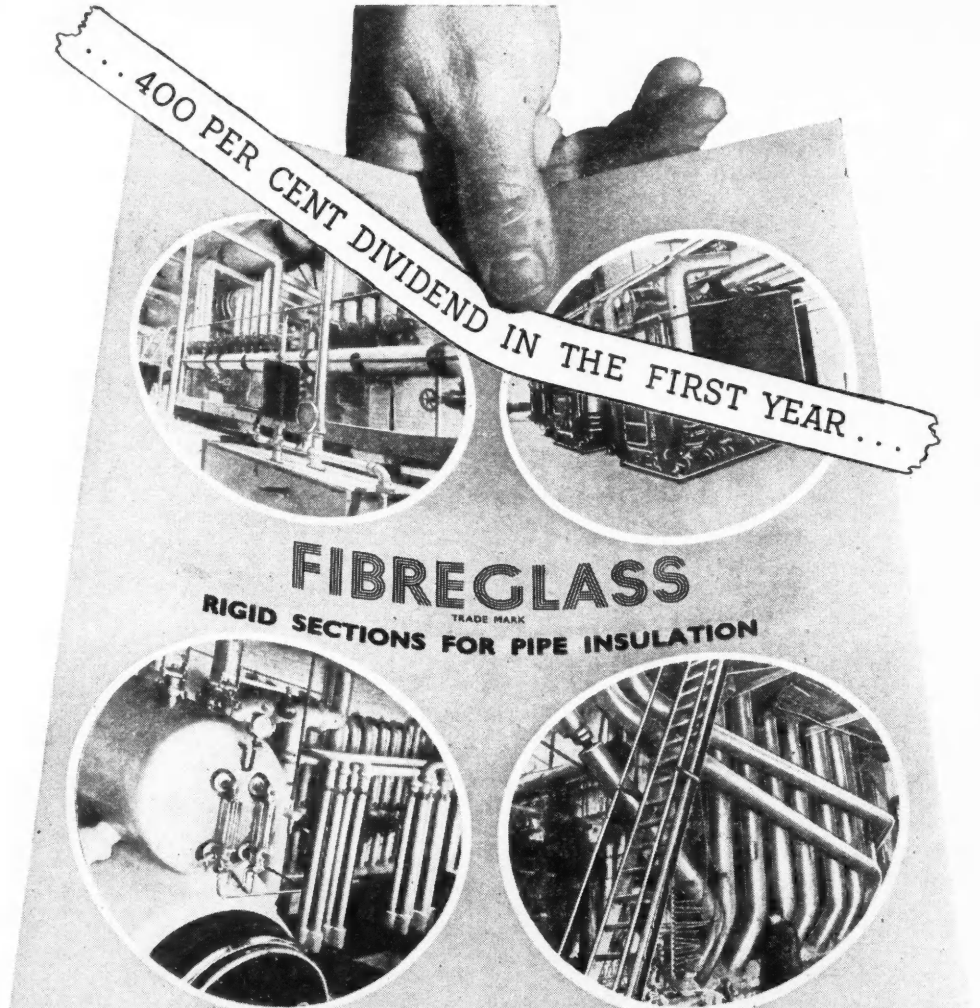
It has been recognised only recently that brittle materials do not possess specific strengths. In fact, the stress required to produce their fracture can vary with changes in state of stress, rate of loading, time under stress, and size. However, even in cases where all factors are controlled, apparently identical test specimens, when tested under identical conditions, are known to show widely different fracture stresses. Naturally, such a scattering of strength values presents serious problems in the design of structures embodying brittle materials. It is therefore important to note that recent research has disclosed an effective method of selecting or designing brittle materials for specific applications. Previously, the usual procedure for determining the strength of a brittle material has been to use its " mean fracture stress," as derived from tests carried out on a number of specimens. Thus, a material may be found by test to be able to withstand a stress as high as 30,000 psi, and to have a means strength of 15,000 psi. If, however, the design stress required in a specific case is 10,000 psi, and if tests have shown that a small percentage of the specimens failed at less than 10,000 psi, the material cannot be considered safe for the application considered. The only way to achieve 100% safety would be to use a material with a " zero-failure " strength of 10,000 psi. Statistical treatment of test data affords a practical method of establishing this zero-failure strength, and it is interesting to note that this strength value appears to be independent of the stress state and the size of the specimens.

● *ULTRASONIC INSPECTION OF WELDED JOINTS IN SHIPS*

Although considerable progress has been made in recent years in the non-destructive testing of welds, its full value has probably yet to be realized. An examination of the list of ships which suffered brittle failures in service indicates that these ships were built at a time when performance could be inspected only by visual methods, with perhaps a limited amount of magnetic particle inspection. Magnetic particle inspection can also be used where both sides of a welded joint are inaccessible to radiography. Ultrasonic inspection has not yet found any service application in hull weld inspection. It is, however, reported that a special ultrasonic device is now under development. This device contains two cathode-ray viewers, one to show a plain view and the other to show a cross-sectional view of the weld. The scanning device is mounted on a carriage designed to cling magnetically to a ship's hull and to move along a welded joint at approximately six feet per minute. Two jets are employed, to supply a layer of water as the coupling medium for transmitting the ultrasonic energy to the metal and for picking up the return signal. Needless to say, this method will have to be fully evaluated to determine its reliability in detecting given flaws in welds, before it can be introduced into shipyard practice. Parallel with this proposed technique, the applicability of xeroradiography for weld inspection should also be investigated. This inspection method has still to be improved to a point where it will consistently give the maximum sensitivity required for ship structure inspection.

● *SURFACE HARDENING OF TITANIUM*

In view of the growing importance of titanium as a material for gas-turbine components and other purposes, the development of surface-hardening processes for this material has been the object of thorough investigations in recent years. These investigations were conducted along the following lines :—(a) The formation of a hard compound on the surface as, for instance, of anodised aluminium; (b) the production of a diffusion layer which can be hardened by subsequent heat treatment, such as a layer of steel capable of carburisation ; (c) the attainment of solid-solution hardening effects by the solid solution of oxygen or nitrogen in alpha titanium; and (d) the production of a precipitation-hardening effect, as, for example, internal oxidation of a solute compound. Of these four methods, the solid-solution hardening effect was found to show the greatest promise. Gas and pack carburising produced rough, porous, loosely adherent surface layers. Moreover, treatment at 1400° F and above produced brittleness. While hydrogen treatments increase the surface hardness, they cause serious embrittlement. Also, the surface-hardening effect is low and the affected zone is shallow. An extremely hard surface is developed on titanium by an electrolytic treatment in molten borax, but the usefulness of this process is qualified because of the shallow case and the rough surface produced. A purified nitrogen treatment was found to develop a relatively hard, adherent case between 1500 and



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1800 F. The properties of the case appeared to be adequate for a practical surface-hardening process. The best results were obtained by heating at 1600° F for 16 hours. This treatment results in an average surface hardness of 800 Vickers, the case depth ranging from 0·0024 to 0·0028 in. Investigation of the wear properties is reported to be in progress.

● *NOVEL LAPPING PROCESS*

A recently published invention is concerned with processes of lapping to make two surfaces conform exactly with one another. Lapping processes are most commonly employed in cases where the surfaces to be lapped will undergo relative rotation in service. In the lapping process the two surfaces are first fine-ground and then, while the two surfaces are in contact, one or the other is rotated rapidly, with oil and a very fine grinding powder interposed between the surfaces. As very fine particles of this powder remain on the surfaces, it is difficult to produce a mirror-like finish. In a recent patent, the claim is made that the lapping process can be greatly improved if the surfaces to be lapped are moved in contact with a solution which attacks or coats at least one of the surfaces. This solution will preferably be a phosphate coating solution, particularly if one or both of the surfaces to be lapped is made of cast iron. A typical phosphate coating solution, in which cast iron may be immersed during the lapping process, is stated to contain 19·5 grams of zinc, 23 grams of phosphorus pentoxide (phosphoric anhydride) and 24·5 grams of nitrogen peroxide. To facilitate penetration of this solution between the surfaces, a wetting agent may be added to it. If a grinding powder is used, it is recommended that the final lapping stage be carried out with a powder-free solution. When aluminium articles are to be lapped, a phosphate solution of the kind capable of coating aluminium may be used; a solution containing sodium carbonate is also suitable for the purpose.

● *IMPROVED HEAT-EXCHANGER MANUFACTURING TECHNIQUE*

In spite of numerous improvements in manufacturing technique made in recent years, the fundamental design features of automobile radiators and car heaters have remained unchanged. A typical present-day automobile heater, for instance, may comprise a core of complex design having twenty or more water tubes soldered at their ends to headers. In addition, fins of sheet metal are provided between adjacent tubes, to which they are soldered. The ordinary tube of this core may be made of two sheets of thin metal, suitably embossed to provide passage-ways and soldered together along their edges. It is claimed that by a new method of manufacture, car heaters and automobile radiators can be made with only one core tube. The new design is based upon the fact that a metal tube of sufficient strength and heat-transmission properties can be made rapidly and economically by forming a collapsed tubular body from a strip of thin metal sheet, by folding the strip lengthwise and making a longitudinal fluid-tight joint by crimping and subsequent soldering. This tube is then laced through a mould or forming box, in which the ultimate shape of the tube coil is outlined by correspondingly formed abutments. After insertion, the flat tube is then connected with a source of compressed air supply, so that it becomes inflated and assumes the shape as prescribed by the mould abutments. The rate of air flow and the ultimate pressure are so controlled that excessive stressing of the tube material is avoided.

● *DEVICE FOR BREAKING UP SWARF*

A recent patent describes a simple method of breaking up a length of swarf while it is being formed in a machine tool, such as a lathe, in the shape of a continuously rotating helix. It is well known that the generation of such swarf, particularly when making a deep cut in a steel workpiece with a carbide cutting tool, makes it difficult to keep the machine tool unobstructed by long lengths of swarf; also, there is, of course, a certain element of danger to the operator. It is therefore desirable that the swarf should be broken up into conveniently short lengths and, according to the claims of the inventor, this is successfully achieved by means of his proposed device. The basic feature of this device is that a certain length of swarf helix is laterally fed into a convergent space, where it is gripped until the axial rotation of the swarf builds up a sufficient torsional stress to fracture it. Experiments are said to have shown that with such a device the swarf almost invariably breaks off at the cutting point where, presumably, it is weakened by the elevated temperature caused by the cutting action of the tool. In its simplest form the device consists of two convergent jaws; one of these, down which the rotating length of swarf tends to roll, is serrated, so that the length of swarf jams in the jaws and breaks off at the other end. A suitable device for removing the piece broken-off from the jaws is also provided.

● *PLASTIC CORE FOR WIRE ROPES*

It is reported that, for the first time in the cordage industry, a new all-plastic centre for use as a core in wire rope has been developed. Ordinarily, wire-rope cores are composed of sisal fibre made up in various sizes and lays. A first step in the use of plastic in connection with wire rope was taken a few years ago, when a plastic-covered fibre core was introduced. In the manufacture of the new plastic centre, a special polyvinyl chloride compound is extruded to form the centre. It will be appreciated that, when used as a core, the plastic material must be able to withstand extreme

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pressures, owing to the high tensile stress to which wire ropes are frequently subjected. Also, the core must retain its elasticity and resiliency over long periods and must maintain its flexibility under both high and low temperatures. The cost of the plastic centre is higher than that of all-fibre centres and its application will therefore be restricted to special cases, such as centres in wire-rope sand lines, baling lines, and cable-tool drilling lines in the oil industry. Plastic cores should also prove most useful where wire rope is exposed to acid-contaminated mine water, and in the fishing industry, where sisal fibre may have a tendency to break down under conditions of continuous wetting and drying.

● *NOVEL ELECTRIC INCANDESCENT LAMP*

It is well known that of the energy radiated from the tungsten filament of a modern incandescent lamp only about ten per cent is in the visible region of the spectrum, while the remaining ninety per cent is emitted as heat, mostly in the infra-red region. In fact, increasing the visible light output of incandescent lamps for a given power input has long been a challenging problem. Latest research, however, has led to the discovery that an increased production of visible light at reduced power consumption can be achieved by providing on the interior and or exterior surfaces of the lamp bulb a very thin coating of titanium dioxide, which is capable of reflecting infra-red radiation back to the filament, but which does not interfere with the emission of visible light, except to a negligible degree. In this way the part of the visible spectrum to which the eye is most sensitive is reflected by the coating to the least extent, so that a maximum of light to which the eye is most reactive is transmitted from the lamp filament to the eye. On the other hand, the coating ensures that the infra-red radiation from the filament is reflected to the greatest possible extent. For a tungsten filament the peak of infra-red and heat radiation is at about 10,000-11,000 Angstroms, and tests have shown that the titanium dioxide coating has a reflectivity of about 39% in this wave-length range. As a consequence, the electric power required to maintain the filament at its normal temperature is 10% less than with a conventional uncoated bulb, while the light output is increased by some 15%.

● *THERMOELECTRIC METAL-SORTING INSTRUMENT*

The sorting of metal stocks which have become mixed is a problem of considerable complexity, particularly where materials have very nearly the same composition or where many types are represented in the mixed stock. A thermoelectric comparator has now been designed to simplify the sorting of mixed stock. This instrument uses a pair of metal probes of known composition, which, together with the piece to be tested, make up two thermocouples in series. One probe is heated to a fixed temperature, while the other assumes the temperature of its surroundings. When the probes contact the sample, two thermocouples are formed, one at each junction. The thermoelectric electromotive forces generated at each junction are characteristic of the respective material. For greater sensitivity and more rapid meter response the signal generated by the probe junctions is fed to an amplifier. As extremely small changes in metal composition produce very large changes in the thermal electromotive force generated, the instrument is highly sensitive, and the same material from different heats gives different thermoelectric readings. This is due to small variations in the percentage of alloying constituents and cannot, of course, be avoided. In the case of materials of similar composition, the method may therefore fail to differentiate between the two materials. These difficulties may be aggravated by the influence of heat treatment upon the metal structure and consequently upon the electromotive force generated. As with so many electrical and magnetic inspection methods, this method cannot therefore be considered infallible, and its limitations should be fully realized.

● *MACHINING OF POROUS SINTERED PARTS*

The machining of the porous sintered bodies of the cathodes of electric discharge tubes presents certain problems. When using tungsten as the cathode metal, machining is difficult if the cathode body has been sintered at high temperatures, which may exceed 1800° C. Cutting, prior to the last sintering operation at high temperature, has the disadvantage that shrinkage and deformation often occur with this last sintering operation. Another difficulty arises from the fact that machining of the porous body after sintering tends to close the pores at the surface. The alkaline-earth metal coating to be applied will thus be prevented from diffusing through the metal, and it is this diffusion on which the operation of the cathode is based. According to a recent invention, the refractory metal, such as tungsten, is sintered from powder into a porous body. This porous piece is then impregnated with a metal which has a comparatively low melting point, so that no alloying of the filler metal with that of the porous piece occurs. The impregnated piece can then be machined by turning, drilling, milling, etc. After machining, the impregnated metal is evaporated, so that the piece regains its original porosity. Impregnation of the porous tungsten piece is carried out by immersing it in molten copper held at a temperature of 1350° C in a hydrogen atmosphere. Approximately 7% by weight of copper is absorbed if, for instance, the piece has 83% of the density of compact tungsten. The material will now be ready for machining, without incurring the danger of closing the pores

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by the cutting operation. Subsequently, the copper filler is removed by heating in a vacuum at a temperature of about 1550° C, until the copper has been evaporated completely. This process can, of course, be applied to porous pieces of other refractory metals, such as molybdenum, tantalum, hafnium, etc.

● *HIGH-TEMPERATURE-RESISTANT POPPET VALVES*

Valves of the conical-head poppet type for internal combustion engines are subjected to heavy wear on their annular seating surfaces, and exhaust valves are therefore made of austenitic types of nickel-chromium steels when it is desired to provide the greatest strength and resistance to corrosion. Usually, the standard chromium steels are sufficiently strong for this purpose. A recent invention describes a method by which the conical heads of steel poppet valves can be provided with annular seating surfaces of a material having greater wear and scaling resistance than the material of the valve itself. The new method is claimed to be greatly superior to conventional methods of welding a material of wear-resistant properties to the seating surface. These methods are generally complicated and lengthy, and call for considerable skill on the part of the welder ; moreover, the welding process must be followed by a considerable amount of grinding. The new method, covered by a recent patent, provides that the layer of wear-resistant alloy which is to form the seat of the valve should consist of a pre-formed annulus, such as a wire ring or a sheet-metal ring. If a material is to be used which cannot be fashioned into wires or sheets, it may be employed in the form of sintered rings. This ring is then brought into position and heated by means of induction heating to pressure-welding temperature; when this is reached, the ring is united with the valve body by exerting the requisite pressure. In an alternative method, the ring is melted down, and by means of a graphite or ceramic plunger is pressed on and shaped to the valve body during solidification.

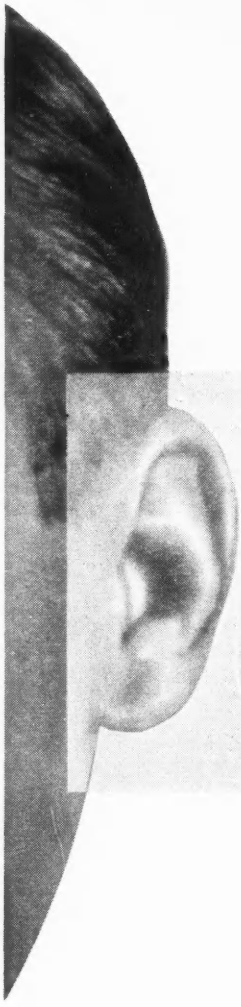
● *CATHODIC PROTECTION BY ZINC-RICH VINYL-RESIN COATINGS*

It has been found that iron and steel can be given cathodic protection against corrosion by coating with vinyl resins saturated with zinc powder. This coating, which also acts as a barrier against corrosion, is anodic and, as it is electropositive, it suffers corrosion while it protects the electro-negative base material. The reason is, of course, that zinc is higher in the electromotive series than iron. In order to be effective, this type of coating must contain metallic zinc powder in sufficient quantity (about 95% after drying) for pigment particles to be in contact with each other. Also, the chemical and physical properties of the zinc used are of primary importance. Particularly, the zinc must be completely free from lead. Two points must be remembered when using this coating :—The vinyl-resin bonding medium is affected by chlorinated hydrocarbons and petroleum solvents ; and the coating must be given 48 hours to dry. Although normal air drying takes only about 40 minutes, two days are needed for complete evaporation and the setting up of galvanic action. Complete ageing will depend upon the moisture in the atmosphere. The longer the coating is exposed to atmospheric conditions or to salt water immersion, the harder it becomes. Before the coating is applied, the surface to be coated must be rendered free from grease, oil, loose rust, and moisture. Adherent rust should be scratched with a wire brush to expose base metal, which acts as an anchor for the coating over the rusted surface. Application of the coating is made by brushing, spraying, or dipping.

● *BORON AS A COATING MATERIAL*

Boron, both in the pure form and in combination with other elements, appears to have a promising future as a coating material for both metallic and non-metallic products, producing surfaces which resist heat, corrosion, and wear. Many of the coatings are exceptionally hard, because they consist of boron, boron carbide, and boron nitride. These coatings are usually formed in place. If the base material is silicon, zirconium, vanadium, or tungsten, borides of these elements can be formed as coatings, to give a wide range of chemical-, wear-, and heat-resistant properties. Boron and most of the borides resist oxidation up to 2200 to 2400° F. Another method of boron coating is to apply alloys of boron as a fused layer on the surface of the base metal. The nickel-base hard-facing alloys now commonly used for resisting wear in corrosive environments contain from 1 to 4·75% boron, where the boron also serves to reduce the melting point. Zirconium boride for jet and rocket nozzles has been given much attention. Some investigations indicate that several of the borides are resistant to molten metals, and will thus prove useful in applications involving the bulk handling of liquid metals. Boron carbide, containing from 2 to 5% aluminium and not over 2% alumina in addition, is claimed to constitute a very hard material, which also has high tensile strength for a material of its class. It is stated to be highly suitable for tools and gauges, and it can be moulded into jet nozzles, turbine blades, impeller blades for handling grit and abrasives, sand-blast nozzles, wire-drawing dies, and even cylinder liners.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.



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